COLORADO DEPARTMENT OF AGRICULTURE

Recommendations for Developing Agricultural Hydropower in Colorado

December 15, 2013
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Simplifying Hydropower

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Executive Summary

According to recent research commissioned by the Colorado Energy Office, Colorado farmers spend an average of about $33,000 per year on electricity. Electricity costs to power irrigation pumps typically make up more than 50% of total electricity expenses.

These costs can be offset by development of hydropower, in many cases taking advantage of existing infrastructure. Colorado has substantial untapped capacity for hydro development utilizing existing agriculture-related infrastructure, including the following:

- **Pressurized Irrigation Systems**: Approximately 7% of Colorado's irrigated land has pressurization potential, primarily located in mountainous areas – most of which could be economically developed as hydropower-driven center pivot irrigation. Over 87% of these irrigated lands are not currently sprinkler irrigated. The statewide untapped capacity of pressurized irrigation systems is approximately **30 MW**, most all of which could be cost-effectively developed given that NRCS has recently confirmed that starting in October of 2014, EQIP funding will be available to fund installation of hydro equipment related to pressurized irrigation.

- **Ditch drops:** An analysis looking at ditches with flows of over 100 CFS or drops of at least 150 feet yielded approximately 123 potential project sites statewide. Many of these sites, however, do not have sufficiently detailed flow information available in order to develop a reliable estimate of hydro generating capacity. In Delta County, where detailed flow information is available, nine sites were identified that are economically feasible under current market conditions and would have a combined capacity of approximately **0.8 MW**.

- **Dams**: Colorado has approximately 102 agriculture-related dams with technical development potential, of which 17 are feasible for development based upon current electricity market conditions, totaling about 40 MW of new capacity. 25 MW are already under development, leaving approximately **15 MW** available for development.

Given current market conditions with relatively low wholesale electricity prices, the most economically attractive agricultural hydro development opportunities are for net-metered, small projects based upon pressurized irrigation pipelines, primarily center pivots, where new hydro installations can help Colorado agricultural producers lower energy costs by offsetting purchases of grid electricity at a full retail rate.

The following three pressurized irrigation project types are recommended as initial areas of focus for a new Colorado agricultural hydropower program:

- Developing new hydro-mechanically driven center pivots.
- Retrofitting existing center pivots with hydro-mechanical drive.
- Retrofitting existing electrically-powered center pivots with new conventional hydropower.

As market conditions change – including higher electricity prices, lower technology costs and better resource data availability -- it may also make sense to develop additional program efforts focused on ditch drops – potentially building upon efforts in Delta County.

The key to success of a new agricultural hydropower program will be availability of NRCS EQIP funding, which can typically pay for 75% of center pivot construction cost, in an amount up to $300K. Center pivots are typically driven by either grid-electricity or diesel generation. The incremental cost of installing center pivot hydro-mechanical equipment is typically about $15K, and adding conventional hydro typically costs between $25K and $50K, a small amount relative to overall typical center pivot installation costs.

Barriers to development of pressurized irrigation hydro projects include the following: lack of industry knowledge of the technology, scarcity of existing installations to serve as reference projects, few equipment suppliers (there is only one company, T-L Irrigation, manufacturing a large center pivot sprinkler irrigation system that can be driven with hydro-mechanical energy), and cost.

Given the availability of NRCS funding which will address the cost barrier starting in late 2014, it makes sense to focus a new Colorado agricultural hydropower program on information and outreach -- with efforts including regional workshops as well as pilot project installations – leading to full program implementation starting in 2015.

Ultimately, a new agricultural hydropower program could help transform the market -- making consideration and utilization of hydropower standard practice in the pressurized irrigation industry.

Introduction

Energy Costs in Colorado Agriculture

As was highlighted in a March 2013 analysis commissioned by the Colorado Energy Office, “Colorado Agricultural Energy Market Research,” electricity purchases can represent a significant portion of operational costs for Colorado agricultural operations. Surveys of farmers in Colorado have indicated that energy expenses are generally about 7% of total operating expenses. In the farming sector, irrigation and its associated electricity costs are one of the largest areas of energy consumption. Colorado farmers report spending an average of about $33,000 per year on electricity, while spending an average of $16,000 on diesel and about $8,000 on gasoline. Electricity costs to power irrigation pumps typically make up more than 50% of total electricity expenses. In 2008, electricity expenses for the entire Colorado agriculture sector were estimated to be $137 million.

Prior Colorado Hydropower Related Efforts

Various Colorado agencies have previously supported efforts related to hydropower.

In 2007, the Colorado Energy Office completed a statewide renewable resources assessment, “Connecting Colorado’s Renewable Resources to the Market,” which included a discussion of Colorado hydropower resources.

In 2010, CDA supported work by Applegate Group to develop a report, "Exploring the Viability of Low Head Hydropower in Colorado's Existing Irrigation Infrastructure.”

In 2010, the Colorado Energy Office signed a memorandum of understanding with the Federal Energy Regulatory Commission (FERC) to create a streamlining program for Colorado small hydro projects. The state’s small hydro permitting program -- which was implemented by SRA International -- was designed to assist developers of small, low-impact hydropower projects in applying for a FERC permit. Projects that qualified for the program were required to use existing infrastructure and have very low potential impacts on the environment. The program pre-screened 26 applications for acceptance into the Colorado program. Nine projects successfully completed the Colorado program and were submitted to FERC for review. Six Colorado projects received a FERC exemption through the program, two of which have been built: a 23-kW irrigation pipeline project near Meeker (see attached Wenschhof Cattle Ranch case study) and a 40 kW project by the Town of Basalt.

In 2011, CDA supported small hydro work by iCAST which included completion of six preliminary feasibility studies for agricultural hydropower applications and two in-depth feasibility studies. iCAST also compiled information about key factors in determining if sites are technically and financially viable, including, most importantly, the site owner’s willingness, interest and patience in developing the site -- which was cited by iCAST as the most important factor -- in addition to physical factors including available head and flow, grid proximity, water rights and options for a power purchase agreement or net metering arrangement. iCAST also developed a short guidebook designed to introduce the basics of micro hydro development, including information about site surveying, power calculations, preliminary economics, permitting, design, construction, commissioning, and operations and maintenance.

In 2013, the Colorado Energy Office retained Telluride Energy and Applegate Group to develop a Colorado Small Hydropower Handbook which provides a step by step overview of the small hydro development process.

Current CDA Project History

In December of 2012, CDA issued a policy paper explaining a new direction for the Advancing Colorado's Renewable Energy (ACRE) program. The purpose of the ACRE program is to promote the feasibility and development of agricultural energy-related projects. Given the limited CDA financial and technical resources available to pursue the diverse array of potential energy technologies and processes in Colorado agriculture, CDA decided that ACRE's purpose is best served by focusing the program's resources on a few themes that can have the greatest impact on Colorado agricultural producers – one of which is agricultural hydropower.

Summary of Available Agricultural Hydropower Potential

In order to understand the small hydropower opportunity within agricultural operations, research was performed into the current market. Three areas for hydropower potential related to agriculture were identified: 1) on-farm pressurized irrigation systems 2) conduit drops on ditch systems and 3) existing agricultural dams. Both the technical potential and the economic potential of each type of hydropower were evaluated to quantify the amount of untapped resource that is available for development.

The technical potential of a site refers to its ability to produce hydropower given the conditions available, namely elevation drop and water flow. Some sites that are technically feasible, having adequate head and flow, may not be economically feasible if the costs outweigh the benefits. The economic feasibility considers all of the costs associated with developing a site and compares that to the electricity offset and revenues generated. For the purposes of this report we have defined economic feasibility as recovering the initial investment within 20 years. It is assumed that 10% of the project cost would be invested at the start of the project, and the remaining 90% of the project cost will be borrowed through a 20 year low interest loan. In order to be considered economically feasible, after the 20 year period the project will have generated enough revenue to service the debt and return the initial investment.

The determination of economic feasibility is based on current market prices for both electricity and power plant components. Sites with a capacity less than 25 kW are assumed to be "net metered" to take advantage of the retail rate of electricity, which has been estimated at $95 per MWh. Sites over 25 kW are assumed to sell the electricity generated back to the local utility at a wholesale rate; currently wholesale rates are about $40 per MWh. A change in either of these market conditions could change the status of some sites from economically infeasible to economically feasible. Additional financial incentives could also change the economic feasibility of projects.

A report which explains the data and methodology used to develop these results is included in Appendix I. The report also includes more detail on the identified sites and statewide potential.

Pressurized Irrigation System Analysis

There are roughly 2.7 million acres of land under irrigation in the State of Colorado. The analysis found that 7% of these lands, or approximately 175,000 acres, are candidates for pressurized irrigation systems. Only 13% of the lands that are candidates for pressurized irrigation systems are already sprinkler irrigated; the remaining 87% are predominantly flood or furrow irrigated.

There is an opportunity to generate hydropower at a gravity-pressurized irrigation system, e.g., a center pivot sprinkler, provided that there is either excess flow or excess head available. The pipeline used to deliver irrigation water to the sprinkler system can also provide pressure and water to a hydropower plant. There are several configurations that are possible depending on the amount of excess head and flow available and the proximity of the electrical grid. It may also be possible to retrofit existing center pivots that currently depend on diesel generators or the electrical grid. Two examples were recently developed in Colorado and are explained in more detail in the appendixes as well as in the sidebar at right.

In order to quantify the magnitude of this opportunity across the state, a GIS based approach

Agricultural Hydropower without Electricity

The owner of Bear River Ranch, located near Steamboat Springs in western Colorado, installed a hydro-mechanical system to power the ranch's center-pivot irrigation system. The system uses the power of falling water to directly drive and pressurize the center pivot, eliminating the need for electricity and significantly reducing operating expenses. Center pivot systems save both water and labor associated with irrigation and can increase crop yields.

The 5.2-kW turbine installed in 2012 uses 126 feet of head and 560 gallons-per-minute to produce power to drive the center pivot's hydraulic pump. The $13,000 project was funded through $6000 in support from the NRCS Environmental Quality Incentives Program (EQIP), yielding out of pocket cost to the ranch of $7000 and an expected payback of slightly over 3 years.

The EQIP program provides financial and technical assistance to farmers and ranchers for the planning and implementation of natural resource conservation efforts, including energy conservation. During 2011, EQIP allocated more than $26 million for nearly 800 projects in Colorado. For Bear River Ranch, the NRCS grant lowered installation costs enough to make NRCS the only outside source of funding needed to complete the project, which avoided $22,000 in grid interconnection costs and $2,100 in estimated annual electricity costs. The project ran through recent irrigation seasons with no problems and increased crop yields -- using less water than had historically been used with flood irrigation.

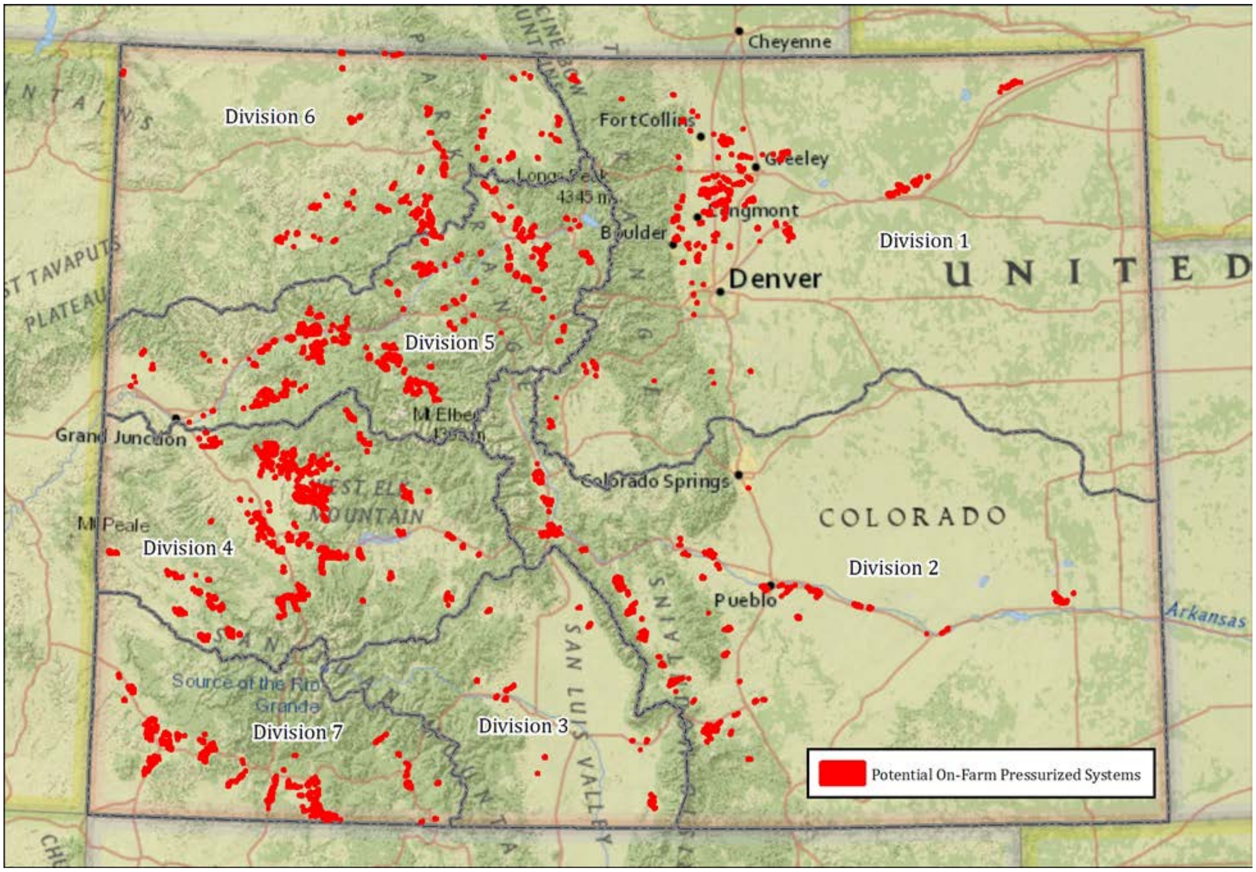
Many ranchers in the area have expressed an interest in installing the same type of system. The local NRCS office hopes to offer design services, aiming to replicate this type of system throughout Colorado.

was taken. Irrigated lands, canals and ditches along with elevation data were mapped for each water division in the state. These geographic data provided the information needed to identify lands with sufficient elevation difference and water flow to both pressurize an irrigation system and generate hydropower.

The power generation potential of all of the lands that are candidates for pressurized irrigation systems (in excess of the power needed to pressurize the irrigation systems themselves) was estimated to be 30 MW. Depending on the situation at a given parcel, this excess power could be used to offset other electrical loads or to mechanically drive the sprinkler system itself.

						Power Potential [kW]	
Colorado Water Division	**Total Irrigated Area [ac]**	**Number of Fields with Pressurization Potential**	**Area with Pressurization Potential [ac]**	**% Total Area with Pressurization Potential**	**% of Pressurization Area Already Under Sprinklers**	**Including Pressurization**	**In excess of Pressurization**
1	830,546	774	22,558	2.7%	33%	5,192	1,132
2	465,526	702	24,704	5.3%	9%	8561	4,114
3	512,001	111	2,239	0.4%	16%	567	164
4	286,254	1,136	49,598	17.3%	5%	19,310	10,382
5	226,375	1,271	38,441	17.0%	13%	14,861	7,942
6	213,973	227	13,853	6.5%	6%	4,975	2,481
7	176,454	729	24,073	13.6%	15%	7,598	3,265
Total	2,711,129	4,950	175,466	6.5%	13%	61,064	29,480

The map below shows areas of potential for generating hydropower within on-farm pressurized irrigation systems.



Conduit Drop Analysis

Ditch and canal drops are another area of potential for hydropower development in the agricultural sector. Open ditches and canals are typically built at a very gradual slope, but where changes in the topography are encountered, a steep slope may occur over a short distance. Commonly these locations are already equipped with a hydraulic structure to dissipate the energy in the falling water. Rather than dissipating the energy, the energy could be harnessed to generate electricity, making these locations good candidates for hydropower development. A GIS based approach was used to identify these drops. Canal and ditch alignments were overlaid on elevation data and an algorithm was developed to identify drops that matched predetermined criteria.

The data available for ditch and canal alignments across the entire state are relatively general. It was sufficient to identify these drops, but does not include the information about flow necessary to determine the power potential at each site. More detailed ditch mapping data were available in Delta County and this made it possible to identify the drops and estimate power potential along with the drop's technical and economic feasibility.

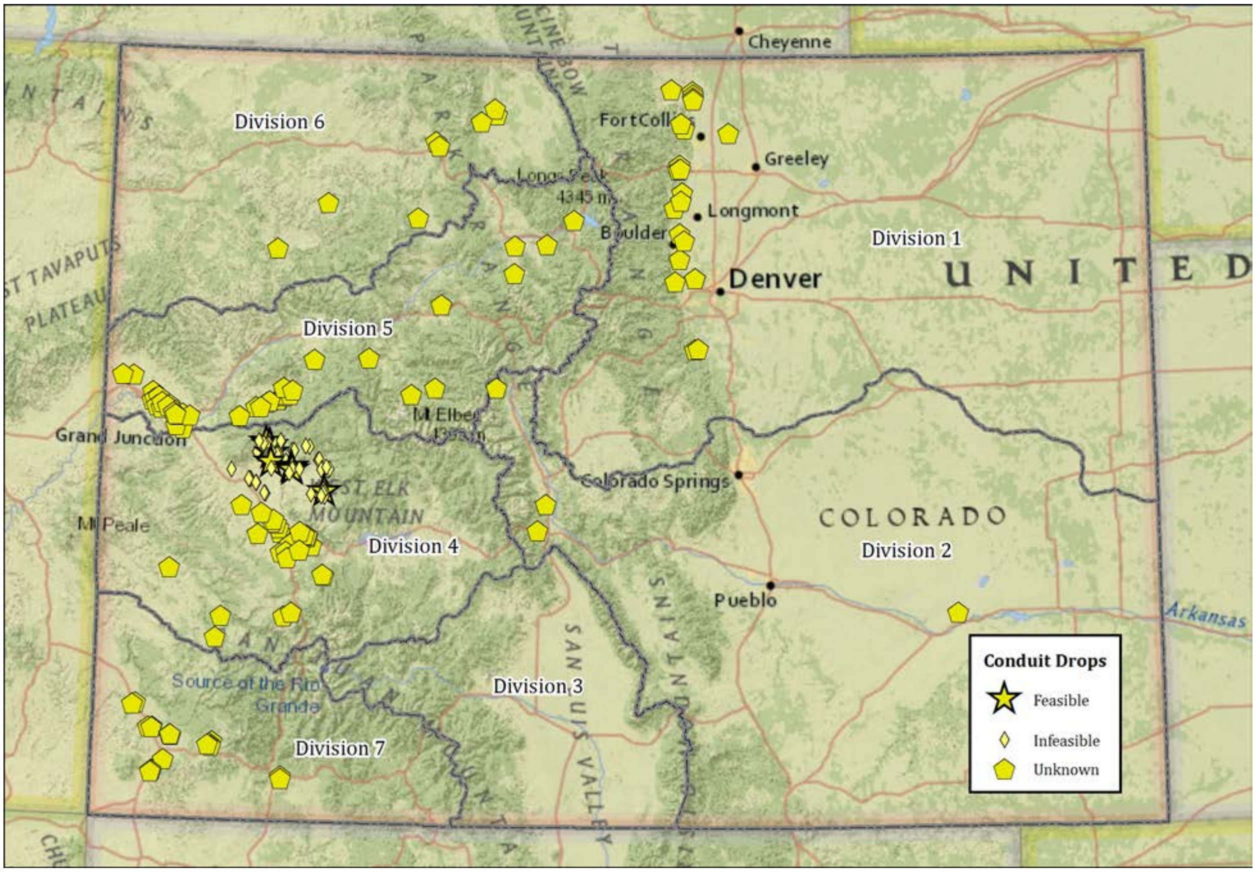
Within Delta County, a total of 77 distinct conduit drops were identified with the potential to produce approximately 3.1 MW of electricity and generate approximately 12,100 MWh per year. Under current electricity market conditions (with pricing as noted above) we determined that 9 sites with a total capacity of 0.8 MW were feasible for a payback period of 20 years or less.

Observations from the data available in Delta County led to conclusions regarding the conditions necessary statewide for an economically feasible ditch drop project. These conditions -- sites with at least 100 cfs of flow or over 150 feet of head -- were used to identify sites across the rest of Colorado.

Using the more general information available for the rest of the state, and the constraints mentioned above, an additional 123 drops were identified. However, the capacity or power generation potential of those sites could not be quantified due to the lack of specific flow information at the drops.

Colorado Water Division	Number of Sites	Total Drop Height of all sites	Number of sites Evaluated by USBR
1	23	1,594	0
2	4	408	1
3	0	0	0
4	104	8,507	23
5	43	4,507	9
6	8	1,070	0
7	18	1,204	4
Total	200	17,290	37

The map below shows the location of potential ditch drop sites and notes which sites were found to be economically feasible, infeasible or did not have enough information to make the determination.



Existing Dams Analysis

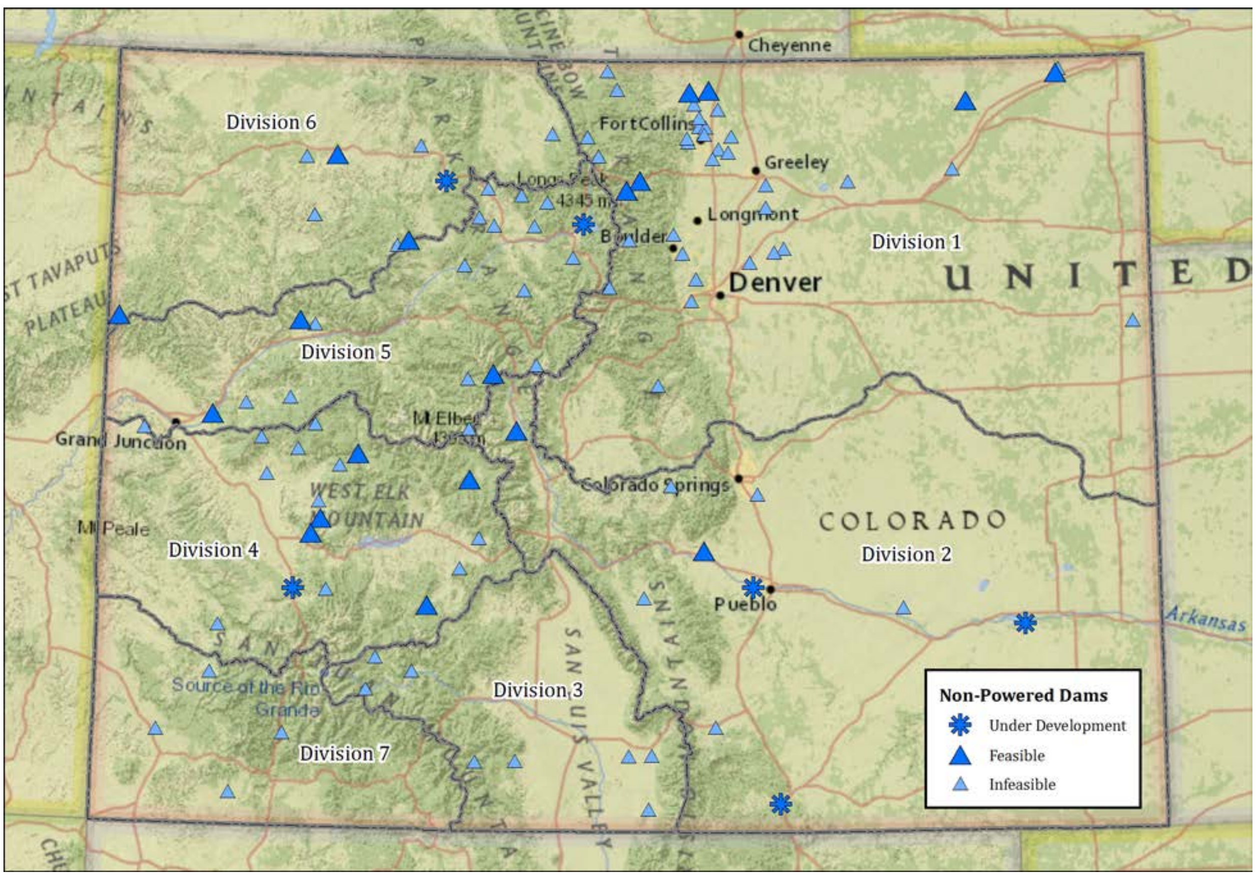
The hydropower potential of existing dams has been explored by various organizations, including federal agencies. These previous studies were used as a starting point for this analysis. There are over 2,000 dams in the State of Colorado, a large number of those dams are very small or only hold water for a very short period of time. The list of dams was narrowed down to exclude dams that were not related to agriculture, on federal lands, or were so small that they were very unlikely to hold potential. More detailed and site specific information was collected for the narrowed list of agricultural dams. This more detailed information included actual historical release records and staff gage readings when available.

Statewide, 106 dam sites were evaluated in detail, of which 102 dams were found to have the technical potential to generate hydroelectricity. Twenty three sites were found to be economically feasible and could break even within 20 years. These 23 sites account for 75% of the total capacity (of the 102 dams) although they are only 22% of the total sites. This shows that the largest capacity projects are the most economically feasible.

The 23 economically feasible sites total approximately 40 MW of capacity, 25 MW of that capacity (6 projects) is currently under development, leaving about 15 MW of untapped, economically feasible potential throughout the state.

Colorado Water Division	**Number of Dams with Technical Potential**	**Estimated Total Capacity of technically feasible projects [kW]**	**Estimated Total Capacity of economically feasible projects over 20 years [kW]**
1	38	4,989	1,919
2	10	16,984	15,084
3	7	4,750	0
4	16	15,518	13,749
5	19	9,889	8,481
6	8	679	191
7	4	746	0
Total	102	53,555	39,424

The following map shows the agricultural dams in Colorado that have technical potential, also noting which have economic potential and which are already under development.



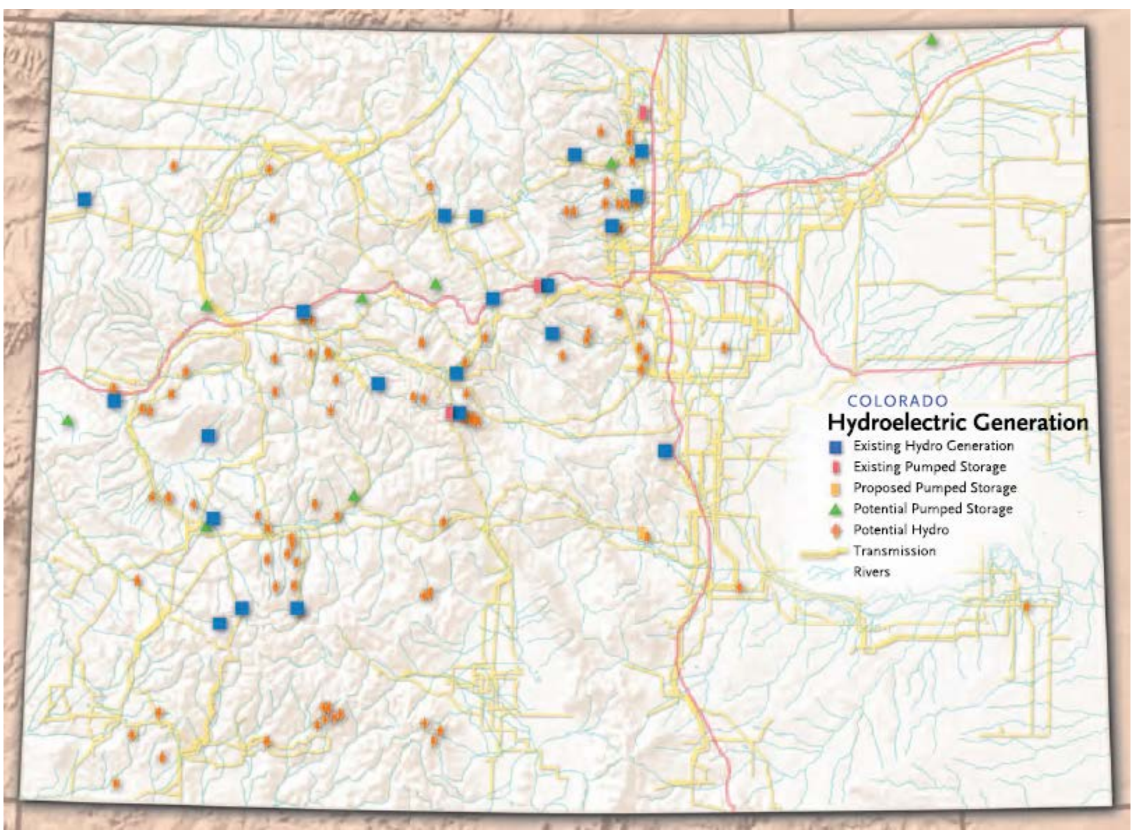
Background on Hydropower in Colorado

Current Hydropower Installations

The majority of hydropower in Colorado was installed prior to 1990 with relatively few installations in the last 20 years. Currently, there are fifty-nine operating hydropower facilities in Colorado, based on a 2012 inventory by the Environmental Protection Agency (EPA), including five pumped storage projects (see appendixes for additional information).

These sites have a combined installed capacity of approximately 1,160 MW and produce 680,180 MWh of electricity annually. These plants range in size from 600 kW to over 150 MW. The plants' construction dates range from as early as 1905 to newer plants built in 2007.

EPA data do not include new projects, including the Carter Lake project recently completed by the Northern Colorado Water Conservancy District and the recently completed South Canal project by Delta Montrose Electric Association. The 8 MW Ridgway Reservoir hydro project being completed by Tri-County Water Conservancy District is expected to go online in 2014.



Colorado's Hydroelectric Generation

Source: Colorado Energy Office, Renewable Resource Generation Development Areas Task Force. *Connecting Colorado's Renewable Resources to the Markets.* December, 2007.

Colorado Hydropower Barriers

There are a variety of barriers to small hydropower development in Colorado, including the following:

Federal permitting requirements have been a barrier to development for decades, although recently they have been largely addressed through federal small hydro permitting reform legislation. On August 9, 2013, President Obama signed into law two pieces of legislation aimed at making the regulatory process more efficient for small hydro: H.R. 267, the *Hydropower Regulatory Efficiency Act*, and H.R. 678, the *Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act*. Prior to the new legislation, federal permitting requirements for small hydro projects had been time-consuming and costly. Prior to the new 2013 law, for smaller systems, the cost of federal permitting could exceed the cost of the hydro equipment needed.

The *Hydropower Regulatory Efficiency Act* solved this problem by creating a "regulatory off-ramp" from FERC permitting requirements for non-controversial hydro projects on existing conduits, such as pipelines and canals, that are less than 5 MW in capacity – provided that there are no objections to the project during a 45-day public notice period. To date, three small hydro projects in Colorado (Silverton, Telluride, Orchard City) have applied to FERC requesting exemption under the new law and two (Silverton and Orchard City) have already received their final FERC exemptions thanks to the new law.

State permitting barriers include requirements associated with complying with state environmental and historical preservation requirements. These requirements will likely be addressed during the 2014 Colorado legislative session through legislation currently being developed by the Water Resources Review Committee, following up on a Committee meeting held on October 10th. The new federal legislation does nothing to change state law, so it is conceivable that a hydro project could receive a rapid determination of exemption from FERC jurisdiction and then later still have to contend with a lengthy state agency review process (for example, through the State Historical Preservation Office, etc.). The intent of the draft proposed new state small hydro reform legislation is to create a new state process to ensure that if any state agencies do have hydro project concerns, they are noted and recorded in a timely way accordingly to the 45 day public comment period recently established by FERC under the new federal law. The goal is to create a new combined federal and state review process to enable a project developer to be able to simultaneously secure federal and state approval within 45 days. Upon successful completion of the FERC process, a Colorado hydro developer could be confident that the only remaining regulatory requirements would be from local government (for example, for compliance with any local government building codes) as well as with electrical inspection requirements.

Interconnection barriers for small hydro vary according to utility. A grid-connected small hydro project will typically be required to secure an interconnection agreement as well as a power purchase agreement. Net metered systems (typically under 25 kW) need to have a net metering agreement. Net metering is an electricity sales arrangement for consumers who develop small renewable energy facilities. Under a net metering agreement, generated electricity is used directly by an adjacent facility. Meters record electricity usage in both directions, meaning electricity can either be consumed from the grid or the excess generated electricity can be exported back onto the grid. For projects located within the service territory of rural cooperatives, customer-sited generation cannot typically exceed 10 kW for residential projects and 25 kW for non-residential projects -- absent special utility approval -- which may or not be available. For projects located in the service territory of Colorado's two investor-owned utilities, Xcel and Black Hills, net metering projects must not exceed 120% of the customer's average annual consumption. Many Colorado rural cooperatives receive electricity wholesale from Tri-State. Pursuant to Tri-State policy 115, member cooperatives are limited to purchasing 5% of their energy locally. Some Colorado Tri-State Colorado cooperatives, including San Miguel Power Association and Delta Montrose Electric Association, have already reached this limit, rendering additional development difficult without the ability to secure a local power purchase agreement.

Electrical inspection approval has also been a barrier to small hydro in Colorado. Currently, there is inconsistent application and enforcement of state code for small hydro approval. Incremental costs associated with post-manufacture, in-the-field product listing and approval can adversely impacts the economic feasibility of hydro installations.

Related to the pending CO small hydro reform legislation as noted above being discussed by the Water Resources Review Committee, the Colorado Small Hydro Association (COSHA) is seeking to persuade the State Electrical Board that there is relevant code precedent from the small wind industry in the 2011 National Electrical Code – precedent which could be directly relevant to the small hydro industry. COSHA is hoping to reach consensus with the State Electrical Board regarding proposed changes to the 2014 Colorado code which would simplify approval for small hydro based on the same "exemption from listing requirement" exception which currently benefits the small wind industry.

Financing and cost barriers remain significant, although these have started to be addressed through funds available through the Colorado Water Resources and Power Development Authority, Colorado Water Conservation Board, and, most importantly, USDA.

The Colorado Water Resources and Power Development Authority (CWRPDA) has a feasibility grant program which can provide up to $15,000 in 50% cost-shared funds to support feasibility studies, permitting, final design and other costs associated with FERC or Bureau of Reclamation permitting processes. CWRPDA also has a small hydropower loan program which can lend up to $2M at a rate of 2% for project construction. CWRPDA-eligible borrowers include cities, towns, counties, water districts, water and sanitation districts, metropolitan districts, water conservancy districts, water conservation districts, and irrigation districts. Loans are limited to a maximum of $2 million per governmental agency. The interest rate is two percent, and the maximum term is twenty years.

The Colorado Water Conservation Board (CWCB) also has a hydro loan program that can finance the engineering and construction of hydro projects with loan terms of 30 years at an interest rate of 2%. There is no maximum loan amount; however, borrowers are required to first apply to the CWRPDA for the initial $2 million of funding and the CWCB loan will the finance the remainder of the project costs. In addition to governmental agencies, the CWCB can also lend to agricultural borrowers. CWCB funds have recently been substantially depleted because of the recent flood events in Colorado, although CWCB funds are expected to potentially be available again by the end of 2014.

In early December, USDA announced a new loan program which could help support development of agricultural hydropower. USDA plans to provide rural electric cooperatives up to $250 million to lend to business and residential customers for energy efficiency improvements and renewable energy systems, potentially including agricultural hydropower. Some rural cooperatives have already developed effective on-bill financing programs which make it possible to pay back borrowed funds for project construction through a regular monthly bill payment – a program model which could potentially be applied to agricultural hydropower if there is interest from a Colorado rural electric cooperative in developing such a program.

USDA’s longstanding Rural Energy for America Program (REAP) could also be leveraged to support agricultural hydropower. Under the REAP program, guaranteed loans and combinations grant/guaranteed loans are available to help agricultural producers purchase and install renewable energy systems. Grant funding under REAP is limited to 25% of total project costs. Loans and grant/loan combinations can cover up to 75% of total project costs. Additionally, REAP can offer low cost energy audits and cost share for renewable energy feasibility studies.

Most importantly, in a letter from NRCS dated November 17th (see appendixes), NRCS stated that hydro equipment could become an eligible reimbursable equipment type under the NRCS EQIP program starting in FY 2015.

Technology barriers are starting to be addressed by companies developing new technologies specifically focused on low-head as well as hydrokinetic applications, although equipment costs still tend to be high. Because of permitting and other barriers, the U.S. small hydro industry is relatively immature, with a small number of equipment providers manufacturing a small amount of equipment annually.

In this study, we have focused on “standardized turbines,” turbines that are designed and manufactured to fit a certain range of head and flow conditions. Manufacturers of standardized turbines generally choose 2 to 5 standard models to cover a larger range of sites, but allow for standardization. This standardization can reduce the cost of a turbine, but also limits the sites for which it is appropriate. Alternatively, a custom turbine is designed and manufactured for specific site conditions. A custom turbine will match the conditions at a site, and extract an optimal amount of energy from a site, but in general the cost will be higher than a standardized turbine. Standardized turbines may also be best suited for other conditions at a site, e.g., bolt onto an existing pipe, or fit into an existing structure. This again limits the standardized turbine applications, but may reduce the cost of the civil infrastructure needed to develop the site. Additional information is contained in the technology discussion in the appendixes.

Information barriers are a result of, among other factors, relatively few existing installed agricultural hydro installations. Currently, most Colorado agricultural producers have no understanding of available small hydro options and no direct experience with small hydro equipment. Factors that will help drive a Colorado agricultural producer to be interested in small hydro include first-hand experience with the technology, ready access to factually correct information regarding to how to proceed with development, and most importantly, economically compelling information regarding the benefits of installing small hydro.

The Colorado Energy Office has started to address these information barriers through their recent development of a Colorado Small Hydro Handbook. To date, however, there has not been any effort to develop small hydro information products or outreach strategies targeted specifically to the Colorado agricultural community. There is precedent for product-specific outreach targeted at the Colorado agricultural community. NRCS, for example, has previously promoted construction of hoop houses to facilitate construction of low-cost greenhouses. Similar targeted outreach by NRCS in conjunction with available NRCS financial support could potentially play a transformative role in raising awareness of agricultural small hydro.

Related Small Hydro Efforts by the Department of Energy

Starting on December 16, 2013 in Denver, the U.S. Department of Energy is convening the first meeting of a “Small Hydro Innovation Collaborative” which has been tasked with developing a report that will provide a look at how small hydropower can be furthered in a cost-effective manner. The effort will also include development of a database of information that will be useful to the small hydropower community as well as a policy agenda to advance small hydropower.

The reports generated by the new DOE effort (which will include participation by one of the authors of this report) will include project design, technology concept and examples within each element of the small hydro development process -- with an intent to stimulate and focus discussion and cooperation among developers, vendors, researchers, regulators and other stakeholders about how to reduce costs of small hydropower.

Small Hydro Efforts by Other States

Colorado has been one of the most active state governments in supporting small hydropower, although some other states have also developed related efforts.

In 2012, the Vermont Legislature passed, and the governor signed, S. 148, “An act relating to expanding development of small and micro hydroelectric projects.” One provision in S. 148 directed Vermont’s Department of Public Service to enter into a MOU with FERC “for a program to expedite the procedures for FERC’s granting approvals for projects in Vermont that constitute small conduit hydroelectric facilities and small hydroelectric power projects.”

The Vermont state agencies responsible for implementing the legislation believe they can accomplish the requirements of S. 148 through better interagency coordination and developer support and have elected not to pursue an MOU with FERC. As such, the Vermont Public Service Department, Agency of Natural Resources, Agency of Commerce and Community Development, and Division for Historic Preservation entered into a multi-agency MOU which outlines the assistance and support Vermont will provide to small hydro developers. Under S.

148, the VT/FERC MOU is supposed to result in an “MOU Program” that includes at least 5 hydro projects to be approved and commence operation. Vermont is also developing a small hydropower developer guidebook and a project intake form to help make the state approval process easier.

The states of Wyoming and Montana are developing a small hydropower guidebook modeled on Colorado’s recently-developed small hydro guidebook.

The State of Oregon has been very active in developing efforts to support small hydropower. In 2009, the Energy Trust of Oregon completed a report on small hydropower development, “Small Hydropower Technology and Market Assessment.” The purposes of the report were to develop an understanding of the technologies, project types, configurations, and associated costs appropriate for hydropower development in Oregon and to develop an understanding of the current conditions, barriers, and opportunities related to the formation of a functional hydropower installation market in Oregon.

The report listed barriers to creating a robust market for small hydro in Oregon, including the following:

- Lack of internal expertise;
- Permitting being too complex, expensive, time-consuming and inhibiting; and
- Difficult interconnection processes.

The report recommended actions needed to move the Oregon small hydro market forward, including the following:

- Providing a paid expert to help those interested to navigate the developmental process;
- Raising awareness about the Oregon Energy Trust’s hydro support by increasing outreach;
- Creating a roadmap of all permitting requirements;
- Creating long-term certainty in available incentives since the development process can span years (Oregon has related state tax incentives); and
- Using existing diversions and infrastructure; leveraging planned construction, such as added hydro when new and replacement pipes are already being constructed.

Electricity Markets

Hydropower resources can be most cost effectively developed where producers can receive maximum value for energy generated. Areas where projects can receive the maximum value depend upon local utility policy as well as state law. Currently, wholesale electricity prices are at relatively low levels in historical terms due to the abundance of natural gas, which has had the effect of driving down electricity prices, with regional wholesale electricity prices in the range of 3-4 cents/kWh.

Colorado has a recently-increased Renewable Portfolio Standard (RPS) requirement which may ultimately help in the development of small hydropower projects. Investor owned utilities must have 30% renewables by 2020, electric cooperatives 20% by 2020, and municipal utilities serving more than 40,000 customers must have 10% renewables by 2020. Colorado's RPS also includes REC-value multipliers for RPS compliance purposes for "community-based" projects located in Colorado.

In addition to Colorado's statewide RPS, some Colorado utilities have incentives which can support hydro project development. For example, in July of 2012, Holy Cross Energy announced a new hydro tariff with a standing offer to purchase hydropower from projects less than 100 kilowatts starting at a rate of 8.5 cents/kWh. Holy Cross also offers a Renewable Energy Generation Capacity Based Incentive which will pay up to $1.50 per watt of installed capacity for renewable electricity generation using hydropower. Holy Cross will also provide net metering for consumers installing renewable energy generation facilities up to 50 kW.

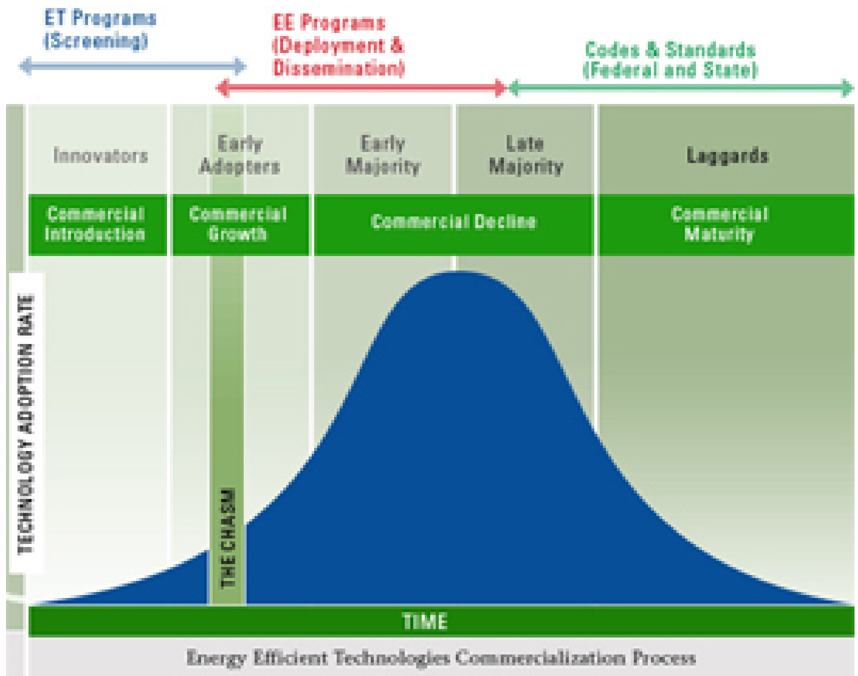
Theoretically, agricultural hydro projects which operate during irrigation season could help utilities to offset their peak load costs since, in some cases, utility peak loads can be caused by high irrigation season demand. Highlighting these synergies could potentially enhance utility interest in supporting agricultural small hydro.

Overall, however, given relatively low wholesale electricity prices, the most economically attractive project opportunities are for net-metered or mechanical systems, typically less than 25 kW, whereby agricultural producers could receive the full retail value of energy produced, which can mean payment rates of 9-10 cents/kWh (as opposed to wholesale rates of 3-4 cents/kWh).

Collaboration for a Market Transformation Effort

Market transformation is the process of intervening to change a market by eliminating barriers. The ultimate goal of market transformation is typically to make utilization of a new technology standard practice in the marketplace. Government market transformation efforts were pioneered by EPA's voluntary programs (including Energy Star) about twenty years ago, starting with energy efficient lighting. Since then, various federal and state agencies have pursued market transformation strategies – which could potentially be applied to the Colorado agricultural hydropower market.

The objective of market transformation can be illustrated by the graphic shown below. Initially, a small number of people may buy target products, so-called "early adopters," but the technology does not yet have a large base of customers. This is where market transformation can play a role, getting these new products to a broader market penetration. This can be achieved by removing barriers and developing efforts to get the target technology to become more widely used. This can be done through informational programs as well as through rebate programs to lower costs and also through new policies and standards.



Source: American Council for an Energy Efficiency Economy

Market Transformation Example for Energy Efficient Technologies

Given the relatively close relationships between existing state agencies and Colorado organizations interested in agricultural hydropower, it should be possible to develop new collaborative efforts to maximize available resources of all relevant Colorado federal and state agencies and organizations.

For example, in additional to budget resources to support agricultural hydropower, CDA strengths include visibility in the Colorado agricultural community and existing information dissemination mechanisms. Other organizations will have additional relevant resources which could be engaged to support a new Colorado agricultural hydropower program, including the following (see appendixes for additional information):

- Colorado Water Resources and Power Development Authority (CWRPDA)
- Colorado Water Conservation Board (CWCB)
- Natural Resources Conservation Service (NRCS)
- Colorado Energy Office (CEO)
- Colorado Rural Electric Association (CREA)
- Bureau of Reclamation (USBR)
- Colorado Small Hydro Association (COSHA)
- Colorado State University Extension (CSU Extension)
- Ditch and Reservoir Company Alliance (DARCA)
- American Rivers (AR)

By convening a statewide agricultural hydropower planning meeting including representatives from organizations listed above, CDA could create a group understanding of individual organizational strengths and weaknesses to inform decision-making regarding the most useful role that each organization could play to support a new Colorado agricultural hydropower program.

Proposed New Colorado Agricultural Hydropower Program

As noted above, given current electricity market conditions with relatively low wholesale prices, the most economically attractive project opportunities are for net-metered systems, typically less than 25 kW, whereby electricity producers can receive the full retail value of energy produced, which can mean payment rates of approximately 9-10 cents/kWh.

Given Colorado's history of leadership in small hydro development and related existing institutional infrastructure, Colorado is well poised to pioneer development of a new agricultural hydropower program to *transform the marketplace to make consideration and utilization of hydropower standard practice in the pressurized irrigation industry.*

As noted previously, the key to success for a new agricultural hydro program focused on pressurized irrigation will be NRCS EQIP funding, which can typically pay for 75% of center pivot construction cost, in an amount up to $300K. Center pivots are typically driven by either grid-electricity or diesel generation. The incremental cost of installing center pivot hydro-mechanical equipment is typically about $15K, and adding conventional hydro typically costs between $25K and $50K, a small amount relative to overall typical center pivot costs.

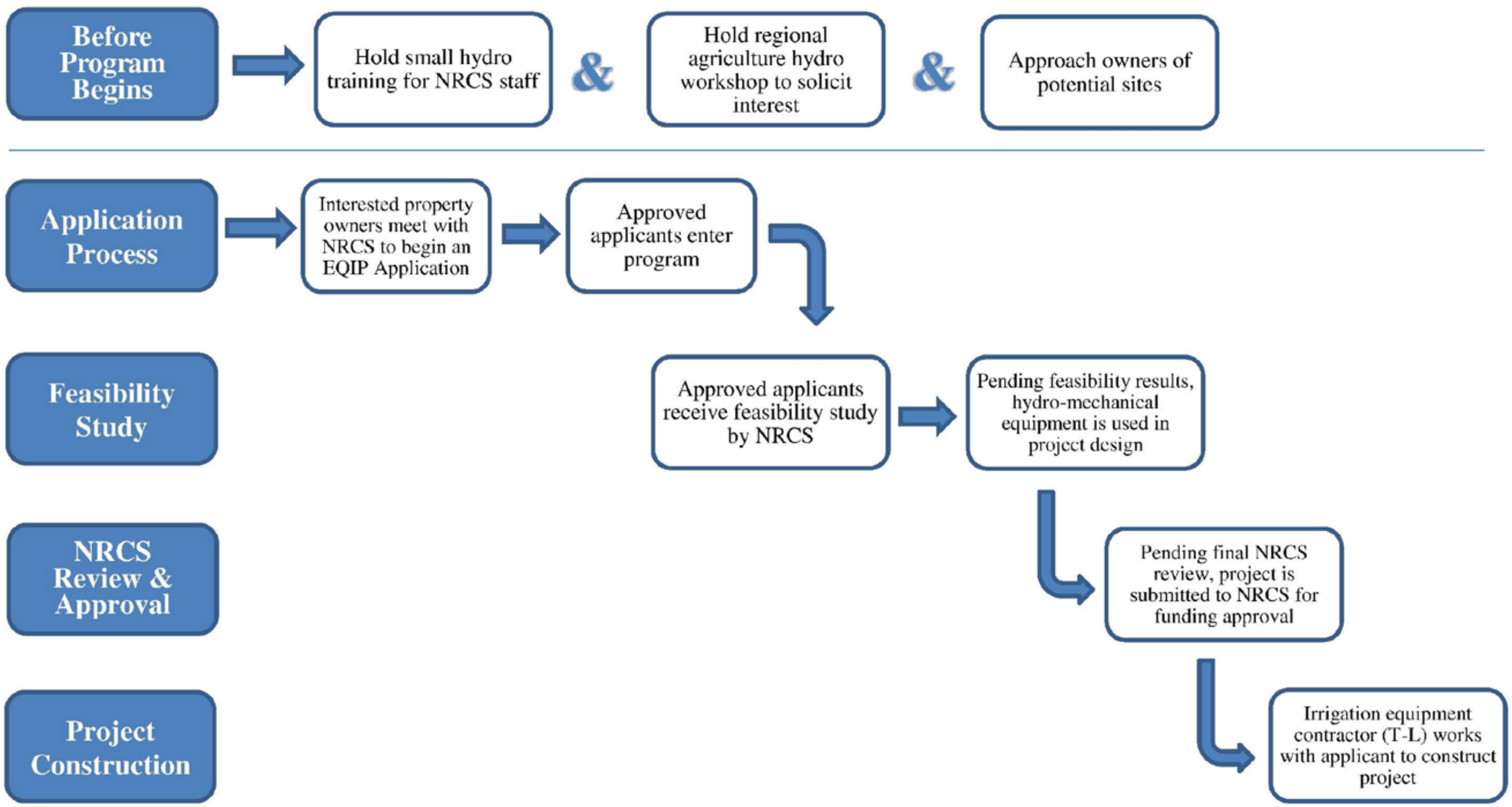
Given the recent clarification (see Appendix E) that the NRCS EQIP program can fund small hydro, the following three project types are recommended as initial areas of focus for a new Colorado agricultural hydropower program:

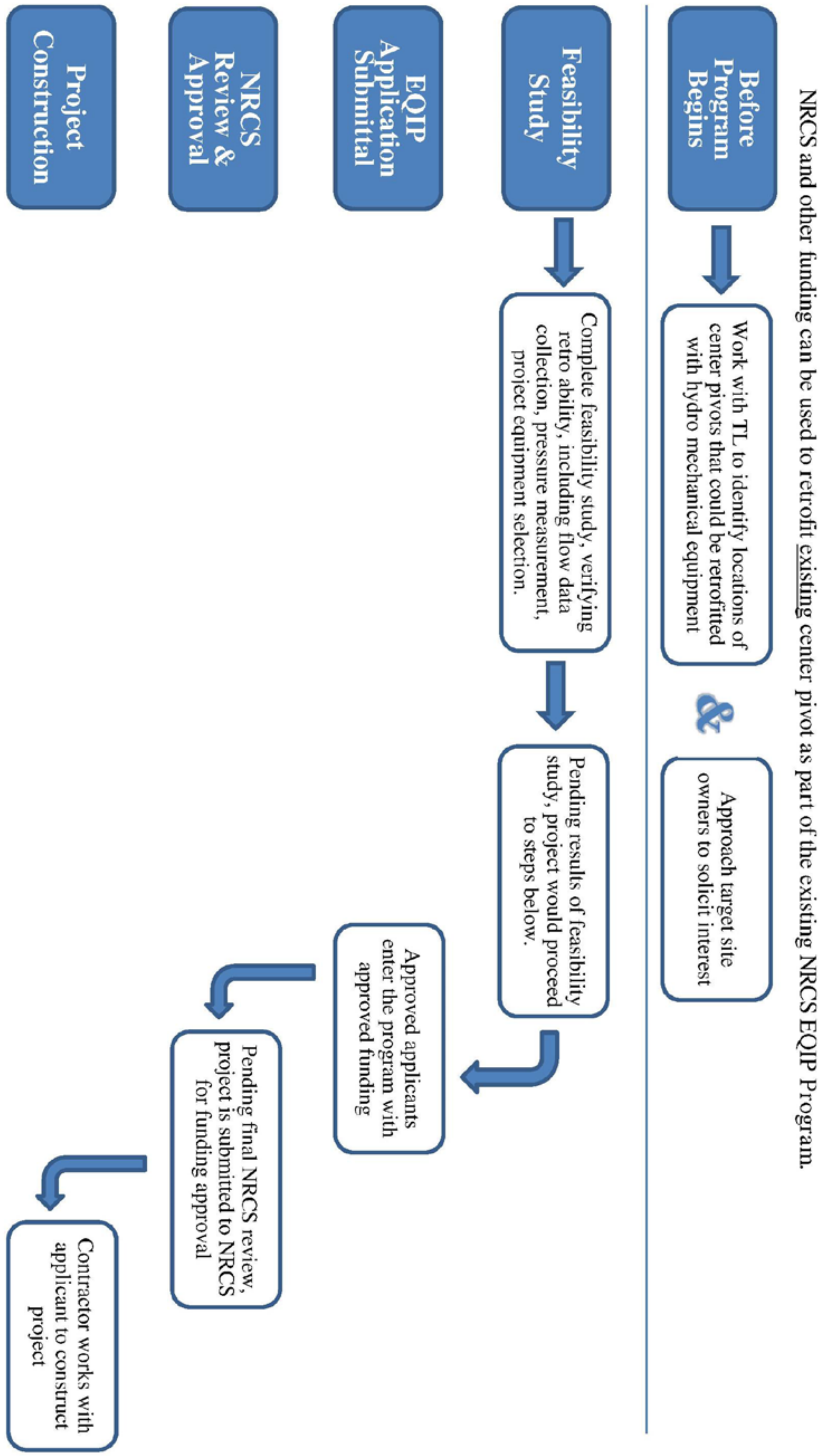
- Developing new hydro-mechanically driven center pivots.
- Retrofitting existing center pivots with hydro-mechanical drive.
- Retrofitting existing electrically-powered center pivots with new conventional hydropower.

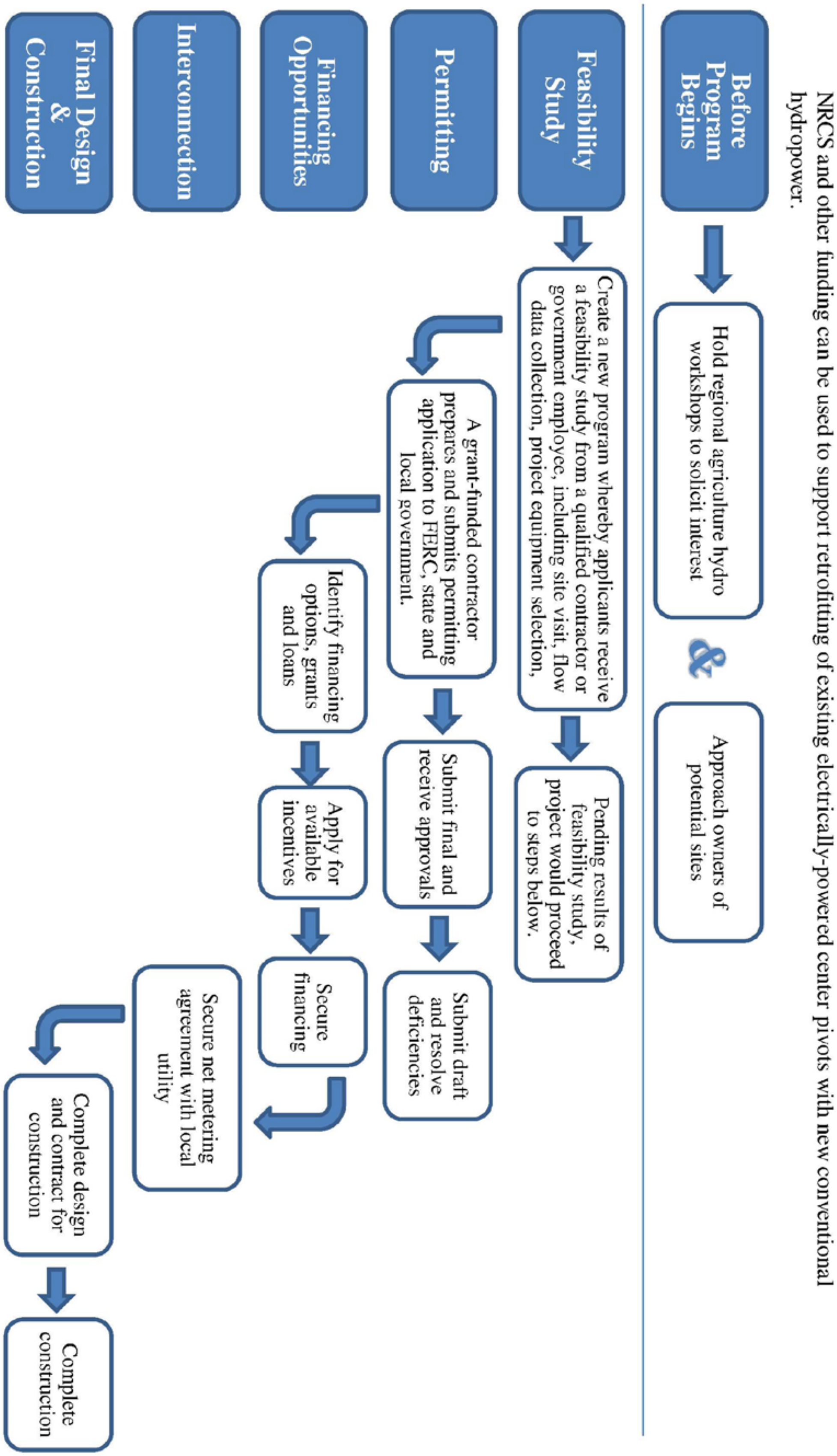
The program sequence for each of these three proposed project types could proceed as outlined in the following diagrams:

Construct New Hydro-Mechanical Center Pivot Installations

NRCS and other funding can be used to integrate assessment of hydro potential and completion of engineering to use hydro-mechanical energy to drive new center pivots as part of the existing NRCS EQIP program.




Retrofit Existing Center Pivots with Hydro-Mechanical Equipment
NRCS and other funding can be used to retrofit existing center pivot as part of the existing NRCS EQIP Program.
Before Program Begins
Work with TL to identify locations of center pivots that could be retrofitted with hydro mechanical equipment
&
Approach target site owners to solicit interest
Feasibility Study
Complete feasibility study, verifying retro ability, including flow data collection, pressure measurement, project equipment selection.
Pending results of feasibility study, project would proceed to steps below.
EQIP Application Submittal
Approved applicants enter the program with approved funding
NRCS Review & Approval
Pending final NRCS review, project is submitted to NRCS for funding approval
Project Construction
Contractor works with applicant to construct project


Hydropower on Existing Infrastructure
NRCS and other funding can be used to support retrofitting of existing electrically-powered center pivots with new conventional hydropower.
Before Program Begins
Hold regional agriculture hydro workshops to solicit interest
&
Approach owners of potential sites
Feasibility Study
Create a new program whereby applicants receive a feasibility study from a qualified contractor or government employee, including site visit, flow data collection, project equipment selection,
Pending results of feasibility study, project would proceed to steps below.
Permitting
A grant-funded contractor prepares and submits permitting application to FERC, state and local government.
Submit final and receive approvals
Submit draft and resolve deficiencies
Financing Opportunities
Identify financing options, grants and loans
Apply for available incentives
Secure financing
Interconnection
Secure net metering agreement with local utility
Final Design & Construction
Complete design and contract for construction
Complete construction

Program Benefits

The National Hydropower Association estimates 5.3 jobs created per megawatt of conventional new hydro construction. Assuming all 30 MW of pressurized irrigation capacity are built in Colorado, that could yield approximately 150 jobs, including jobs for developers, engineers, concrete workers, plumbers, carpenters, welders and electricians.

Most of the job creation and economic development benefits will take place in rural areas. After a new center pivot small hydro project is complete, it creates an ongoing economic benefit for farmers and ranchers, helping to offset electricity costs in perpetuity as long as the project remains operational.

Program Costs

Program costs will depend upon the available resources from related federal and state agencies and organizations which will determine the magnitude and scope of what can likely be accomplished. For example, COSHA may be able to host regional agricultural hydropower workshops, and presumably NRCS will be able to further specify exactly what kinds of small hydro project costs will be allowable under the NRCS EQIP program starting in FY 2015.

During the proposed statewide planning meeting, individual program implementation costs could be discussed -- including costs associated with project feasibility assessments as well as hydro equipment cost. Given that NRCS EQIP funding for hydro will not be available until FY 2015, CDA may wish to provide funding for equipment costs starting in 2014 in order to accelerate construction of “reference projects” at locations strategically dispersed across the state in areas with a high concentration of pressurized irrigation potential.

Future Programmatic Efforts Related to Irrigation Ditch Drops

In addition to proceeding with new statewide efforts focused on pressurized irrigation, it may also make sense to explore development of irrigation ditch drops.

As noted earlier, Delta County has better ditch drop data available than anywhere else in the state because, as part of a Colorado River salinity mitigation effort, the U.S. Bureau of Reclamation funded development of a GIS-based data set regarding irrigation water flows in Delta County which was developed in cooperation with the Delta Conservation District. The salinity project gathered data regarding 131 ditches in Delta County, including detailed data regarding ditch drops and flows at each drop site. The data gathered for the salinity analysis were used to assess opportunities for hydropower development in Delta County.

Of the 77 ditch drop sites in Delta County, 59 were found to be technically feasible, meaning there was an existing standardized or custom turbine whose operation envelope encompassed the head and flow conditions at the site. Under current conditions (assuming wholesale rate of \$40/MWh and net metering offset rate of \$95/MWh), nine sites with a total capacity of 0.8 MW were feasible for a payback period of 20 years or less. Two sites with a total capacity of 0.4 MW are feasible for a payback period of 10 years or less. Five of the nine sites which are economically feasible are net-metered projects.

CDA could potentially assist ditch companies in Delta County to develop the sites that have been identified in this report as economically feasible. Delta County also has in place all the elements necessary to develop a successful collaborative regional effort, with good relationships in place among all relevant local stakeholders in the region. This opportunity could be discussed at a proposed regional agricultural hydropower workshop to take place in Delta County. For additional information, see Appendix G with substantial additional detailed information regarding agricultural hydropower in Delta County.

In addition to pursuing pilot ditch drop efforts in Delta County, CDA may wish to provide information from this report to other conservation districts across the state regarding how to most effectively gather ditch drop flow data in order to accurately assess potential for hydro development at irrigation ditch drops – information which could potentially support development of additional statewide efforts focused on ditch drop hydropower.

Suggested 2014 Program Plans

In order to start new program efforts in agricultural hydropower, the following activities are recommended for 2014:

- **Convening a statewide meeting of organizations that could help realize the agricultural hydropower potential identified in this report**. The purpose of the meeting will be to review research results from this agricultural hydropower report and seek consensus on a plan to leverage the combined resources of existing Colorado organizations to support development of agricultural hydropower. The meeting could include presentation of each of the three initial project types – including discussion of relevant barriers along the way – so that participating organizations could consider how they would be able to most effectively participate. Organizations to invite may include the following: American Rivers, Colorado Small Hydro Association, Colorado Energy Office, Colorado State Extension, Colorado Rural Electric Association, Colorado Water Conservation Board, Ditch and Reservoir Company Alliance, Natural Resources Conservation Service, U.S. Bureau of Reclamation. Additional information, including a proposed draft meeting agenda, is contained in the additional attachments below. Presumably the final 2014 agricultural hydropower program plan will be completed after the statewide meeting in a way which captures information gathered at the meeting.

- **Preparing a MOU between the Colorado Department of Agriculture and relevant federal and state agencies, including NRCS.** The purpose of the MOU(s) will be to spell out roles and future planned cooperation in order to take advantage of Colorado's untapped potential for agricultural hydropower. Presumably this will include NRCS support related to project engineering, but it may also include USDA as well as CWRPDA and others related to project funding. The goal will be to maximize all available existing resources in order to deliver meaningful technical and financial support to Colorado agricultural producers (see additional attachments for a draft MOU between CDA and NRCS).

- **Compiling an agricultural hydropower handbook.** The handbook, which could use the recently-developed small hydro handbook from the Colorado Energy Office as a starting point, should include recent changes in federal small hydro permitting requirements as well as additional technical information regarding pressurized irrigation installations (see additional attachments below for a preliminary draft outline for a new agricultural hydropower handbook).

- **Conducting a small hydro training for NRCS staff.** The purpose of the training, based upon the new agricultural hydropower handbook described above, will be to ensure that NRCS staff are able to accurately assess whether a given center pivot site has sufficient pressure available to warrant installation of small hydro -- for both new applications as well as for potential retrofits for existing center pivots -- using either hydro-mechanical or conventional hydro to provide electricity to power an existing center pivot.

- **Refining statewide estimates for the two target project types.** This additional data gathering could include all three of the target project types as noted above. Currently, there is only one manufacturer of large center pivots which can potentially be fitted with hydro-mechanical equipment (T-L Irrigation), so refining the target retrofit list can presumably be completed by analyzing T-L location information in conjunction with the new pressurized irrigation location information contained in this report, as well as by consulting with area NRCS contacts who are usually familiar with the center pivots in their area.

- **Supporting a series of agricultural hydropower workshops.** Workshops could be located at host utilities and/or irrigation districts. The purpose of the workshops will be to share information about agricultural hydro opportunities. Target sites for 2014 workshops -- based upon proximity to appropriate project sites as well as likely-supportive local utilities -- include Delta, Glenwood Springs, and Fort Collins. Workshops could include presentations on new resource assessment data contained in this report, agricultural hydropower technologies, project financing, relevant federal and state government resources, as well as case studies. Likely workshop attendees will include agricultural property owners interested in hydro development, current hydro owners and operators, utilities, environmental organizations, state and local officials, and equipment vendors. It may make sense to hold the first regional workshop in Delta County given the high quality agricultural hydropower resource data available in the region.

- **Issuing a solicitation to fund installation of approximately six demonstration projects by the end of 2014 located across Colorado.** Projects could be similar to the projects highlighted in the attached case studies. The purpose of the projects will be to provide geographically-dispersed “reference projects” which can serve as case studies.

- **Evaluating 2014 program results and planning for 2015.** Program evaluation metrics could include the number of new agricultural hydro installations, the amount of new generating capacity installed, and total expected annual energy savings. Presumably the new agricultural hydropower program would begin full implementation starting in 2015 with a detailed program implementation strategy being developed based upon results from 2014.

Conclusion

Colorado has a history of leadership and innovation in small hydropower and had the right ideas about small hydro 120 years ago: it makes sense to harness available mechanical energy with small hydro systems wherever available -- generating distributed, reliable, renewable energy.

In 1891, the Ames Hydroelectric Generating Plant near Telluride, Colorado went online with engineering by Tesla. The 3.5-megawatt Ames hydro plant was the world's first power plant to generate, transmit and sell alternating-current electricity for commercial purposes.

In 2013, the Delta-Montrose Electric Association, together with the Uncompahgre Valley Water Users Association, completed development of the South Canal hydro plant, one of the largest agricultural hydropower projects in the U.S.

Thanks to leadership from Colorado's Rep. DeGette and Rep. Tipton, new small hydro permitting reform legislation was signed into law in 2013, removing regulatory barriers which have been hindering development of the small hydro industry for decades. And in November of 2013, NRCS confirmed that it would make hydropower an eligible reimbursable type of equipment as part of the EQIP program – creating a meaningful financial resource to support development of agricultural hydropower.

Colorado is ideally poised to develop an effective, collaborative new effort to support development of agricultural hydropower given its untapped hydro resources as noted in this report and effective working relationships among relevant agencies and organizations.

A successful new agricultural hydropower program could help create new construction jobs, provide an ongoing financial benefit for Colorado agricultural producers, and potentially serve as a nationwide model for market transformation -- making consideration and utilization of hydropower standard practice in the irrigation industry.

Appendix A: Case Study: Wenschhof Cattle Ranch Hydro Project

Summary
George Wenschhof, a cattle rancher in Meeker, Colo., figured out how to harness the mechanical energy in his center pivot sprinkler irrigation system to power his ranch through installation of a 23-kW hydropower plant from Canyon Hydro. Wenschhof installed a hydroelectric generator to offset the electrical load of his irrigation system and all of his ranch operations. A case study from the Colorado Energy Office notes that the project is saving $10,000 to $13,000 per year in avoided electric bills.

Project Overview
George Wenschhof, a rancher in Meeker, Colorado and the owner and operator of the Wenschhof Cattle Company, participated in the Natural Resources Conservation Services (NRCS) Environmental Quality Incentives Program (EQIP) to convert his irrigation from flood to a sprinkler system. He installed a large center pivot sprinkler system as well as a small hydroelectric generating facility. The turbine produces enough power to offset the electrical demands of the center pivot and all ranch operations.

Project Components
The project included the following components:
- An improved intake and screen at the Miller Creek Ditch.
- Pipeline that feeds both the center pivot sprinkler and the hydroelectric turbine.
- A 23 kW double nozzle Pelton Turbine and induction generator with all associated controls.
- An extension of the three phase power to the power house.
- A power house to house the turbine, generator and controls.
- A discharge basin below the power house, with a small pump that can be used to irrigate lower on the ranch and an overflow pipe.

Project Conclusions

The project has proved to be economically favorable. Mr. Wenschhof was able to utilize the infrastructure put in place for the center pivot to also benefit the hydropower facility. The NRCS assisted the project with funding towards the turbine itself. By only producing enough electricity to offset the demands of the ranch, the value of the electricity produced is the retail rate of close to 11 cents/kWh. This project saves the ranch approximately $10,000 - $13,000 per year in electrical bills. Center pivot sprinkler systems consume a large amount of energy; incorporating a hydroelectric turbine in the center pivot project makes this entire project more cost effective.

Source: Flux Farm Foundation, July 2011

Appendix B: Case Study: Barton Ranch Hydro Project

Roger and Shelley Barton own and operate Barton Farm in Ferron, Utah. The Bartons farm 120 acres of alfalfa and mixed grasses used for horse hay. They irrigate with a center-pivot irrigation system. Diesel fuel is a large expense in operating a center pivot. The Bartons needed to reduce fuel costs and still follow their irrigation schedule.

The Barton's hay fields are located a half-mile from the nearest overhead power line. After considering the cost to have single-phase power run to the field, the Barton's selected a T-L diesel-powered hydraulic center-pivot irrigation system and had it installed in 1998. This T-L hydraulic center pivot is powered by a diesel motor and uses gravity flow to pressurize the irrigation system. A small DC alternator operates the control panel. At the time the irrigation system was installed, the national average cost for diesel hovered at around $1 a gallon. In 2008, the Bartons paid $4.25 a gallon. Fuel costs for the irrigation system were about $4,000 a year and rising.

Roger Barton has eliminated all irrigation fuel costs by integrating a hydro turbine into his existing center pivot. Photo by Roger Barton.

The Bartons met with Ken Gardner, a civil engineer and hydropower specialist with Gardner Engineering, to consider alternative energy options to power their system. They determined that the irrigation system required only about 53 percent of the available water pressure. The additional pressure could be used to power the turbine. The Bartons could keep their existing irrigation system and reduce their fuel costs to zero.

Siting and Layout Considerations

The combination of a hydraulic center pivot and hydro turbine are generally a good match when available pressure exceeds the requirements of the irrigation system by 40 pounds per square inch (PSI) or more. The Bartons receive irrigation water by gravity feed from a reservoir several miles away, which provided 80 PSI of operating pressure at the pivot point, 37 PSI more than required to operate 1,220 feet of pivot and the end gun. The T-L hydraulic pivot installed at the Bartons requires 15 horsepower (HP) to operate correctly.

The Bartons hired Redmond Irrigation in Redmond, Utah to design and install the system. A Cornell turbine from Centex Fluid Products was selected. Centex designs and sells custom hydro turbines, made by Cornell Pump Company, that work with a range of heads, flows and pressures. The basic method of sizing this system included: assessing the flow (the volume of water passing through the pipe), determining the residual (additional) pressure available, calculating any pipe or other head and flow losses and evaluating the technical requirements of the irrigation system. These data were provided to Centex to design the turbine.

Gate valves on the incoming line and discharge allow flow to be incrementally adjusted if necessary and shut the system off for maintenance. Photo by Roger Barton.

The Cornell hydro turbine was coupled with the T-L variable-displacement hydraulic pump using a belt drive. The system is monitored by the T-L control system. A filter was installed before the turbine to remove sand, gravel and other water debris that can damage the turbine impeller. Auto valves with a trip switch automatically shut down flow to the turbine if there is a problem in the system. An integrated 12-volt alternator provides the DC voltage required by the control panel.

Financial Incentives

The cost for design, equipment and installation of this system was $17,000. The Bartons received a $4,000 cost share under the NRCS Conservation Innovation Grant program. The estimated simple payback on the hydro turbine system is 3.25 years. In Utah, NRCS is currently offering a 65 percent cost share for this type of system under the Environmental Quality Incentives Program (EQIP).

System Specifications

- Hydro resource: Gravity flow from reservoir
- Total pressure: 80 PSI
- Additional pressure: 37 PSI
- Head: 162 ft
- Flow: 888 gpm
- Irrigation system: T-L hydrostatic center pivot
- Hydro turbine: Cornell Turbine (5TR5-F16)
- Runner type: Francis
- Pipe: 10 inch steel w/ compression fittings
- Total System Cost: $17,000 (before cost share)
- Incentives: $4,000
- Cost savings estimate: $4,000 annually
- Simple payback estimate: 3.25 years

"One disadvantage we discovered," said Barton "is that water must be running through the turbine to move the pivot." The T-L hydraulic pivot continuously "walks" as long as the turbine is operating. "If you are crossing ground you do not want to irrigate, you may want to install a backup diesel motor in addition to the hydro system", said Barton. Re-nozzling of the pivot may also be necessary to compensate for the reduction in pressure throughout the system.

Roger Barton says farmers and ranchers should be in contact with a knowledgeable consultant early on to determine if they have enough pressure to integrate a hydro turbine. "Once the resource is determined to be sufficient, look at how to reduce the system costs," said Barton. NRCS offers a cost share and the Rural Energy for America Program (REAP) provides grants, through USDA Rural Development.

An integrated hydro turbine with a gravity-flow irrigation system is an excellent opportunity to reduce fuel costs. These systems are simpler than hydro-electric systems. The consistent flow and pressure of a gravity-flow hydro resource allow the turbine to be designed for the specific resource and require very few adjustments down the road.

Source: Hydro Power for Gravity Flow Irrigation Systems
By Leif Kindberg, ATTRA Farm Energy Specialist, May 2010

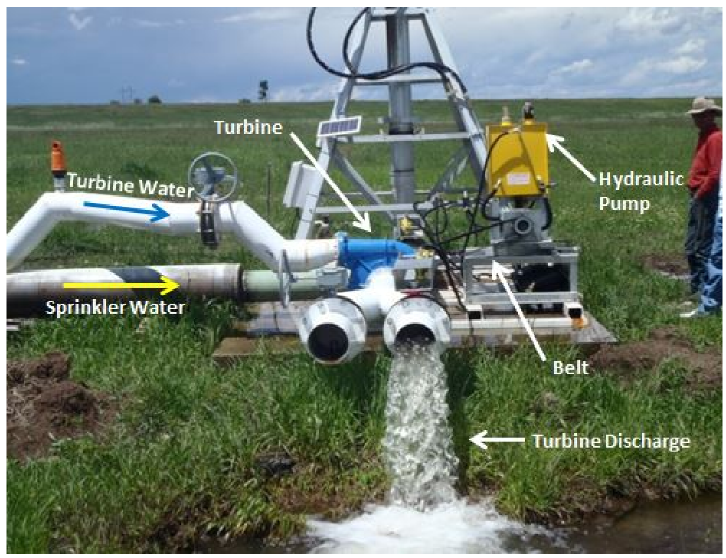
Appendix C: Case Study: Bear River Ranch Hydro-Mechanical Center Pivot Project

Summary

When confronted with rising water costs and low crop yields, Bear River Ranch, located near Steamboat Springs, installed a hydro-mechanical system to power its center-pivot irrigation system. This system uses the power of falling water to directly drive and pressurize the center pivot; this eliminates the need for electricity and significantly reduces operating expenses. The turbine uses 126 feet of head and 560 gpm to produce the equivalent of 5.2 kW of power which drives the center pivot. The $13,000 project was funded through $6000 in support from NRCS, yielding out of pocket cost to the ranch of $7,000 and an expected payback of slightly over 3 years.

Background

The Natural Resource Conservation Service (NRCS) encourages water conservation by supporting the conversion of flood irrigation to sprinklers and also supports renewable energy for on-farm applications. By working with the NRCS for project design and financial assistance, Bear River Ranch was able to achieve both NRCS goals. A center pivot sprinkler was chosen as the water conservation measure, which uses significantly less water than the previous method of flood irrigation. A hydro-mechanical system was installed to eliminate the energy required to power the center pivot.



Key components of the hydro-mechanical irrigation system.

Design and Technical Details

The photograph at right shows the key components of the system: a turbine that powers the hydraulic pump through use of a connecting belt, and water supply lines to power the turbine and provide water to the sprinklers. A single supply pipeline originates from a settling pond at a point 150 feet higher in elevation. This elevation difference pressurizes the water in the pipeline. Just before reaching the center pivot, the pipeline splits into two smaller supply pipes as shown above; the pressurized water powers the turbine (via the pipe denoted with a blue arrow) and supplies the sprinklers (via the pipe denoted with a yellow arrow). The turbine is attached to a shaft which drives a belt connected to the hydraulic pump. The hydraulic pump powers the drive system that moves the center pivot wheels and turns the sprinkler system.

Hydro-mechanical systems are relatively simple, so complex safety and operational procedures are typically not necessary. Because the use of hydro-mechanical systems is relatively rare, a lack of institutional knowledge has prevented their widespread use to date.

The Bear River Ranch turbine produces an equivalent of 5.2 kW or 7 HP to power the hydraulic pump on the center pivot sprinkler system. The hydraulic pump powers the drive system that turns the sprinkler, and the sprinkler is pressurized through gravity. No pumps, motors or electrical connections are required, resulting in very low annual operational expenses and minimal maintenance. Because it does not produce electricity, the project is not regulated by the Federal Energy Regulatory Commission.

The center pivot is operated only during irrigation season, with operation dictated by the crop's water demand. A T-L Irrigation hydrostatic center pivot with manual speed control was selected for the sprinkler system and a Cornell Pump (5TR5) was selected as the turbine. Cornell pumps are easily obtainable due to their dual purpose. Most pumps can be used for both pumping and as a turbine without any modification.

Construction of the hydro-mechanical system was a fast and simple process, spanning only one non-irrigation season. The center pivot distributor, B&B Irrigation, consulted with Jordan Whittaker of Two Dot Irrigation to select the turbine and design the connection. Because the turbine and hydraulic pump are belted together, their power outputs are essentially equivalent. As such, the turbine was sized to provide 7 HP or 5.2 kW which corresponds to the power needed for proper operation of the hydraulic pump. The turbine uses a flow of 560 gpm at the available 126 feet of working head to provide the 7 HP to the hydraulic pump.

Maintenance of the system is very simple. The turbine will need to be maintained as a pump would, with occasional bearing greasing. The center pivot machinery and turbine are generally given a useful lifetime of 20 years, although with proper operation and maintenance, they can last much longer. Premature wear due to debris and sediment in the water is possible and could reduce the expected lifespan of the turbine so care must be taken to adequately filter the water prior to its entry into the system.

Economics

NRCS supported the project in both the design of the irrigation system and partial funding of the entire project through the Environmental Quality Incentives Program (EQIP) program. EQIP provides financial and technical assistance to farmers and ranchers for the planning and implementation of natural resource conservation efforts. During 2011, EQIP allocated over $26 million for nearly 800 projects in Colorado. For Bear River Ranch, the NRCS grant lowered installation costs enough to make NRCS the only outside source of funding needed.

The only cost incurred which varied from that of a traditional, electricity-driven center pivot is that of the turbine; the center pivot sprinkler and pipeline costs were equivalent to traditional center pivot installations. The purchase of the turbine amounted to $13,000 to which the NRCS contributed $6,000, making the out-of-pocket expense for the system $7,000. The system saves estimated annual energy costs of approximately $2,100. Power to spin to the center pivot could alternatively have been obtained through either a diesel generator or grid interconnection if Bear River Ranch had opted for a traditional center pivot irrigation system, but this would result in annual fuel/electricity expenses. If electricity had been extended to the center pivot location, it would have cost $22,000. Center pivot systems using diesel or electricity would have higher installation costs and would have resulted in higher annual expenses. With the hydro-mechanical system, the initial investment by the ranch of $7,000 will be recaptured in 3.3 years of energy savings.

Lessons Learned

The project ran successfully through the 2012 irrigation season with no problems reported and increased crop yields using less water than had historically been used with flood irrigation. Many of the ranchers in the area are expressing an interest in installing the same type of system. Some have submitted applications to the local NRCS office, which is hoping to offer design services for this type of system. Such a system can potentially be replicated throughout Colorado in areas where sufficient pressure can be generated using at least 100 to 150 feet of fall.

Source: Colorado Energy Office, June 2013

Appendix D: Statewide Agricultural Hydro-Related Organizations

Colorado Water Conservation Board (CWCB)

Overview: The Colorado Water Conservation Board (CWCB) provides policy direction on water related issues. The CWCB is Colorado's most comprehensive water information resource. The agency maintains expertise in a broad range of programs and provides technical assistance to further the utilization of Colorado's waters. In a joint effort with the Colorado Department of Water Resources (DWR), CWCB maintains the Colorado's Decision Support Systems (CDSS) database, which among other things, provides Historic Diversion Records and Streamflow Stations data. The CDSS website offers users the ability to search for diversion records using multiple criteria, such as by diversion name, water source, owner's name, and legal location. Streamflow stations can also be searched using multiple criteria, such as by station name or county.

CWCB and Agricultural Hydropower: Use of CDSS data can be helpful when estimating water availability annually or at different times of the year for potential hydropower sites. Once a potential hydropower sites has been identified and a feasibility study commissioned, the CDSS data can be extremely helpful to both developers and engineers in better understanding the site's potential with long-term and accurate flow data.

The CWCB also has a hydro loan program for agricultural borrowers that can finance the engineering and construction of hydro projects with loan terms of 30 years at an interest rate of 2%. There is no maximum loan amount; however, borrowers are required to first apply to the CWRPDA for the initial $2 million of funding and the CWCB loan will finance the remainder of the project costs.

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Colorado Water Resources & Power Development Authority (CWRPDA)

Organization Overview: Colorado Water Resources and Power Development Authority (CWRPDA) is a quasi-governmental organization created by state statute to provide low cost financing for water and wastewater related infrastructure projects to municipalities and special districts. The Authority utilizes several programs to provide funding for local governments' water, wastewater, and hydropower projects including the State Revolving Fund Programs (Water Pollution Control Revolving Fund and Drinking Water Revolving Fund), Water Revenue Bonds Program, and the Small Hydropower Loan Program.

CWRPDA and Agricultural Hydropower: The CWRPDA offers a small hydropower loan program that can lend up to $2 million at a rate of 2% for project construction. Eligible borrowers for the CWRPDA programs include water, water conservancy and irrigation districts. Eligible projects consist of new hydropower facilities (turbines, mechanical and electrical), pipelines, necessary remodel/reconfiguration of the building housing the facilities and transmission lines. Projects must be for facilities of 5 MW or less. The CWRPDA also has a feasibility grant program that can provide up to $15,000 in 50% cost-shared funds to support small hydro feasibility studies and permitting.

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United States Department of Agriculture (USDA)

Overview: USDA aims to expand economic opportunity through innovation, helping rural America to thrive; to promote agriculture production sustainability that better nourishes Americans while also helping feed others throughout the world; and to preserve and conserve our Nation's natural resources through restored forests, improved watersheds, and healthy private working lands.

USDA and Agricultural Hydropower: USDA offers several grant and loan programs that may be applied towards eligible small hydropower.

1. USDA offers the Rural Energy for America Program (REAP). Under REAP, guaranteed loans and combinations grant/guaranteed loans are available to help agricultural producers purchase and install renewable energy systems. Grant funding under REAP is limited to 25% of total project costs. Loans and grant/loan combinations can cover up to 75% of total project costs. Additionally, REAP offers low cost energy audits and cost share for renewable energy feasibility studies.
2. USDA's Farm Service Agency Loans and Farm Ownership loans assist in purchasing or enlarging a farm/ranch, constructing or improving existing buildings, and paying for water conservation or protection measures. A small hydropower project may qualify as “improving existing buildings” as a net metered project would most certainly enhance the buildings current standing. The loan would be under the Conservation Guarantee Loan since hydropower would fall under a “practice of conservation.” The loan interest rate fluctuates on a monthly basis anywhere from 2%-4%.
3. USDA's Operating Loans assist in purchasing equipment and pay for annual operating expenses. A small hydropower project would assist in offsetting a farm’s annual electric

costs, and therefore could be eligible as it would ultimately assist in paying for the operating expenses.

4. USDA's Rural Development, Assistance to Rural Communities with Extremely High Energy Costs provides grants and loans to be used to acquire, construct, extend, upgrade, and otherwise improve energy generation, transmission, or distribution facilities serving communities in which the average residential energy expenditure for home energy is at least 275 percent of the national average. Eligible entities are persons, State and local governments, and federally recognized Indian tribes and tribal entities.
5. USDA's Renewable Energy Projects Guaranteed Loans can finance renewable energy systems such as solar, wind, hydropower, biomass or geothermal technologies.

Contacts:

Donald Nunn USDA Rural Development (720) 544-2907 donald.nunn@co.usda.gov	April Dahlager USDA Rural Utility Service Director, Colorado State Office (720) 544-2909 april.dahlager@co.usda.gov	Gary Wall USDA Farm Service Program Director (720) 544-2892

Natural Resources Conservation Service (NRCS)

Organization Overview: NRCS provides technical assistance and cooperative conservation programs to landowners and land managers throughout the United States as part of the U.S. Department of Agriculture (USDA). The NRCS works with landowners through conservation planning and assistance designed to benefit the soil, water, air, plants and animals that result in productive lands and healthy ecosystems.

NRCS and Agricultural Hydropower: NRCS created the Environmental Quality Incentives Program (EQIP) which is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. Any owners of land in agricultural or forest production or persons who are engaged in livestock, agricultural or forest production on eligible land and that have a natural resource concern may participate in EQIP.

<u>Contact</u>

The information and application differs by county. To find out more information about a given county, visit: offices.sc.egov.usda.gov/locator/

U.S. Bureau of Reclamation (USBR)

Organization Overview: To manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Through leadership, use of technical expertise, efficient operations, responsive customer service and the creativity of people, Reclamation seeks to protect local economies and preserve natural resources and ecosystems through the effective use of water.

Reclamation and Agricultural Hydropower: Reclamation has been particularly involved in supporting new small hydro development in Colorado, with ongoing recent and current projects at Reclamation facilities including Pueblo Dam, Ridgway Dam and Carter Lake.

In addition, the Bureau of Reclamation's WaterSMART grant program can help fund hydro project development. WaterSMART allows Reclamation to work with States, Tribes, local governments and non-governmental organizations to pursue a sustainable water supply for the Nation by establishing a framework to provide federal leadership and assistance on the efficient use of water, integrating water and energy policies to support the sustainable use of all natural resources and coordinating the water conservation activities of the various Interior offices. Eligible WaterSMART grant applicants include States, Indian tribes, irrigation districts, water districts or other organizations with water or power delivery authority located in the western United States. Successful WaterSMART hydro grant recipients typically include not only a hydro project but also some type of additional public benefit, such as salinity reduction or water conservation.

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Colorado State University Extension (CSU Extension)

Overview: Colorado State University Extension is the front door to Colorado State University providing the extensive knowledge, research capabilities and resources of the university to all Coloradans.

CSU Extension and Agricultural Hydropower: CSU Extension aims to provide education and support to those interested in developing hydropower. For those agricultural hydro applications, the process can be overwhelming, so CSU Extension offers a place to gain information on grants, loans, permitting, costs, etc.

One program CSU Extension provides is the Colorado Energy Master Program. The Colorado Energy Master program offers participants an unbiased, comprehensive overview of energy efficiency and renewable energy in Colorado. The program is intended to empower Coloradans to make wise energy decisions and to provide the background information needed to understand broad energy issues. The program offers up to 30 hours of coursework and is open to anyone, including those wishing to become certified Colorado Energy Masters. CSU Extension also provides educational workshops and presentations for groups on energy within Colorado. Additionally, CSU Extension offers numerous other resources to help Colorado consumers make sound energy decisions such as fact sheets, online decision tools, recorded webinars and case studies.

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American Rivers (AR)

Overview: American Rivers protects wild rivers, restores damaged rivers and conserves clean water for people and nature. Since 1973, American Rivers has protected and restored more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects and an annual America's Most Endangered Rivers® campaign.

American Rivers and Agricultural Hydropower: American Rivers has preliminarily expressed an interest in supporting regional workshops aimed at educating and assisting agricultural landowners interested in small hydro.

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Colorado Small Hydro Association (COSHA)

Overview: The Colorado Small Hydro Association (COSHA) promotes the development of small hydropower in Colorado. It works with statewide partners to assist in developing small hydropower. Additionally, it hosts annual meetings to assist and educate interested parties, as well as provide a networking space for those interested in Colorado hydropower.

COSHA and Agricultural Hydropower: COSHA and related interested organizations can partner to promote hydropower development within the state.

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Colorado Energy Office (CEO)

Overview: The Colorado Energy Office (CEO) seeks to improve the effective use of all of Colorado's energy resources and the efficient consumption of energy in all economic sectors, through providing technical guidance, financial support, policy advocacy and public communications. Additionally, CEO aims to help Coloradoans live more prosperous and healthy lives by promoting innovative energy production and efficient energy consumption practices that are beneficial to the economic and environmental health of the state.

CEO and Agricultural Hydropower: CEO created a statewide Hydropower Development Handbook that can be the foundation to CDA's Hydropower Roadmap on Agricultural Applications. CEO's Handbook offers thorough details on all development aspects, ranging from feasibility to permitting to financing.

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Colorado Rural Electric Association (CREA)

Overview: The mission of the Colorado Rural Electric Association (CREA) is to enhance and advance the interests of its member electric cooperatives through a united effort. CREA provides members with education, training and information.

CREA and Agricultural Hydropower: CREA plays a key role in educating its member utilities regarding technology, including small hydropower.

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Ditch and Reservoir Company Alliance (DARCA)

Overview: The Ditch and Reservoir Company Alliance (DARCA) is a membership organization for the benefit of all types of irrigation enterprises - ditch companies, reservoir companies, laterals, private ditches, and irrigation districts. Membership is also open to interested individuals, professionals and government/corporate organizations. DARCA's mission is "to become the definitive resource for networking, education and advocacy" for its members.

DARCA and Agricultural Hydropower: DARCA members would presumably be very interested in new information regarding technology and potential financing available to assist with development of agricultural hydropower.

Contact
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Colorado Farm Bureau

Overview: The stated mission of the Colorado Farm Bureau is “to correlate and strengthen the member county Farm Bureaus; support the free enterprise system and protect individual freedom and opportunity; promote, protect and represent the business, economic, social and educational interests of farmer/rancher members and their communities; and to enhance the agricultural industry in Colorado.”

Colorado Farm Bureau and Agricultural Hydropower: Colorado Farm Bureau members would presumably be very interested in information regarding agricultural hydropower.

Contact
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Rocky Mountain Farmers Union

Overview: The Rocky Mountain Farmers Union is dedicated “to sustaining our rural communities, to wise stewardship and use of natural resources, and to protection of our safe, secure food supply. RMFU supports its goals through education and legislation, as well as by encouraging the cooperative model for mutual economic benefit.”

Rocky Mountain Farmers Union and Agricultural Hydropower: RMFU members would presumably be very interested in information regarding agricultural hydropower.

Contact
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Appendix E: NRCS Letter Regarding EQIP Funding for Small Hydro

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
Denver Federal Center
Building 56, Room 2604
P.O. Box 25426
Denver, CO 80225

November 19, 2013

Kurt Johnson
Colorado Small Hydro Association
P.O. Box 1646
Telluride, CO 81435

Dear Mr. Johnson:

Thank you for your letter of November 5, 2013, regarding the Natural Resources Conservation Service (NRCS) in Colorado providing financial assistance through the Environmental Quality Incentives Program (EQIP) to help producers install micro-hydro components as part of irrigation system improvements. You requested consideration for inclusion of language in the pending Farm Bill discussion to ensure that NRCS had authority through EQIP to support these micro-hydro components.

I am happy to report that NRCS national program leadership has confirmed that sufficient authority currently exists through EQIP to support micro-hydro components. This reimbursement will be made when the component is included as part of a center pivot or other irrigation system improvements addressing water quantity concerns. Unfortunately, the components were not included in the payment schedules for FY 2014 and therefore will not be available this year.

We will be working with our EQIP program managers to ensure that the costs of such devices are included in our EQIP financial assistance practice payments at the earliest possible opportunity and will be available for FY 2015.

I appreciate you bringing this to our attention. Thank you for your commitment in helping agricultural producers address resource opportunities and important energy issues. If you have any questions, please feel free to contact me.

PHYLLIS ANN PHILIPPS
State Conservationist

cc:
Michael Bennet, Senator, U.S. Congress, 835 E. 2nd Ave., Suite 206, Durango, CO 81301
Jason Weller, Chief, NRCS, Washington, DC
Astor Boozer, Regional Conservationist – West, Washington, DC
Wayne Honeycutt, Deputy Chief for Science and Technology, NRCS, Washington, DC
Anthony Kramer, Deputy Chief for Programs, NRCS, Washington, DC

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Appendix F: USDA Press Release Regarding New Efficiency Loans

USDA News Release No. 0228.13
Contact: USDA Office of Communications (202) 720-4623

Agriculture Secretary Vilsack Announces Energy Efficiency Loan Program to Lower Costs for Consumers, Reduce Greenhouse Gas Emissions

Rural Development Loan Program is Latest USDA Effort in Support of Climate Action Plan

WASHINGTON, Dec. 4, 2013 – Agriculture Secretary Tom Vilsack today announced that USDA will take new steps to save consumers money on their energy bills in partnership with rural electric cooperatives. USDA plans to provide rural electric cooperatives up to $250 million to lend to business and residential customers for energy efficiency improvements and renewable energy systems.

"Energy efficiency retrofitting can shrink home energy use by 40 percent, saving money for consumers and helping rural utilities manage their electric load more efficiently," said Vilsack. "Ultimately, reducing energy use helps pump capital back into rural communities. This program is designed to meet the unique needs of consumers and businesses to encourage energy efficiency retrofitting projects across rural America."

Vilsack noted that the Energy Efficiency and Loan Conservation Program, by promoting energy savings in rural areas, is another step by which USDA is supporting President Obama's Climate Action Plan. The program will help build a cleaner and more sustainable domestic energy sector for future generations by reducing barriers to investment in energy efficiency and potentially cutting energy bills for American families and businesses in the process.

Although energy efficiency measures can reduce home energy use considerably, many consumers and businesses do not invest in them because they lack the capital or financing to do so. Consistent with President Obama's Climate Action Plan, this program will reduce barriers to these investments by making financing more available.

Funding will be provided to rural electric cooperatives and utilities – the majority of which already have energy efficiency programs in place – who will then re-lend the money to help homeowners or businesses make energy efficiency improvements. In addition to energy audits, the loans may be used for upgrades to heating, lighting and insulation, and conversions to more efficient or renewable energy sources.

A March 2012 Rockefeller Foundation report on financing energy efficiency projects found that a $279 billion investment could yield more than $1 trillion in energy savings over 10 years. That is the equivalent of 30 percent of the annual electricity spending in the U.S. Funding from the loan program will complement and strengthen other energy efficiency activities at USDA. Through its Rural Development mission area, USDA also supports the research, development and use of renewable fuels.

Vilsack noted that many of USDA's existing efforts to promote renewable energy and energy efficiency are provided by the Farm Bill – and he once again urged Congress to provide a new, multiyear Food, Farm and Jobs Bill that continues investing in a clean energy future for rural America.

The rule is scheduled to publish in the Dec. 5 issue of the Federal Register.
President Obama's plan for rural America has brought about historic investment and resulted in stronger rural communities. Under the President's leadership, these investments in housing, community facilities, businesses and infrastructure have empowered rural America to continue leading the way – strengthening America's economy, small towns and rural communities. USDA's investments in rural communities support the rural way of life that stands as the backbone of our American values.

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Appendix G: Delta County Agricultural Hydropower Report

Introduction

The following information was prepared by Applegate Group and Telluride Energy under contract to the Colorado Department of Agriculture as an appendix to a broader report, "Recommendations for Developing Agricultural Hydropower in Colorado," which analyzed hydro development opportunities for the following three project types:

- Pressurized Irrigation Systems
- Ditch drops
- Existing Dams

The broader report concluded that given current market conditions, with relatively low wholesale electricity prices, the most economically attractive agricultural hydro development opportunities are for net-metered, small projects based upon pressurized irrigation pipelines, primarily center pivots, where new hydro generation can offset purchases of electricity at a retail rate.

The following three project types were recommended as initial areas of focus for a new Colorado agricultural hydropower program focused on pressurized irrigation:

- Developing new hydro-mechanically driven center pivots.
- Retrofitting existing center pivots with hydro-mechanical drive.
- Retrofitting existing electrically-powered center pivots with new conventional hydropower utilizing excess energy available in pressurized irrigation pipelines.

Delta County is well positioned not only to develop the pressurized irrigation project types described above, but also to develop ditch projects based upon having better ditch drop data than anywhere else in the state.

Ditch Drops

Results from Analysis

In 2011, the Delta Conservation District initiated an effort to collect information on the amount of unlined earthen ditches and laterals in the Delta Conservation District and to map the locations of ditches with over 4 cfs of deeded water rights and more than one land owner using a handheld GPS unit. This work resulted in a dataset showing the ditch alignments, headgate locations, typical flows at different locations throughout each ditch, and other information, which was published in January 2012.

A GIS based analysis of this dataset of mapped ditches enabled a quantification of the hydropower development opportunity. The analysis assumed that the current configuration and current use of the ditch or canal was maintained. It also assumed that any one hydropower site would require piping only the portion of the canal where the drop occurred. This assumption optimizes the amount of power that can be produced with the lowest length of canal piping, and therefore the lowest cost. However, there may be additional hydropower opportunity if the canal was piped for a longer distance. In Delta County the USBR Salinity Program may fund the piping of entire canals, which could produce additional hydropower potential that is not quantified in this report.

Of the 77 individual conduit drops identified within Delta County, 59 were found to be technically feasible, meaning there was an existing standardized or custom turbine whose operation envelope encompassed the head and flow conditions at the site. The expected annual revenue from each drop was calculated as the product of the electricity generated and the power purchase rate. If a site was able to be net metered (i.e. power potential of 25 kW or less based on current laws) then the power purchase rate was assumed to be the net metering rate of $95 per MWh; sites larger than 25 kW were assumed to receive a wholesale power purchase rate of $40 per MWh. The development costs for the technically feasible projects were estimated as the sum of the penstock cost, transmission cost, turbine cost, permitting costs, and civil works costs.

The economic feasibility of a project was assessed by comparing the expected revenue to the development cost. The feasibility of the conduit drop projects is very sensitive to the power rate received for generated electricity and any “green” incentives offered. Under current conditions and assuming a 1% operations and maintenance cost, we determined that nine sites with a total capacity of 0.8 MW were feasible for a payback period of 20 years or less. Only two sites with a total capacity of 0.4 MW were feasible for a payback period of 10 years or less.

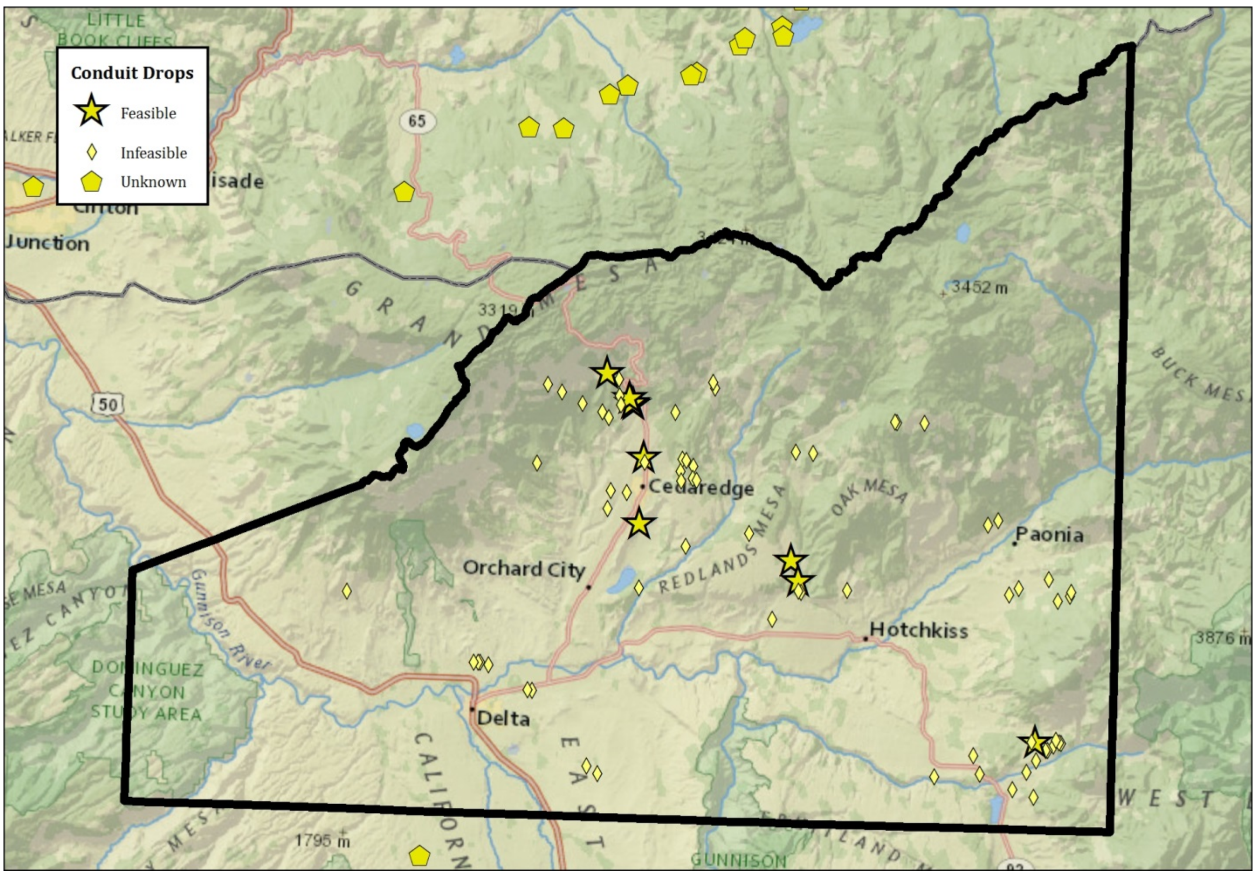
Roughly half of the sites which were economically feasible were sufficiently small to qualify as net metered projects; the other half of feasible projects generated between 60 kW and 350 kW.

Economic Feasibility

The economic feasibility of ditch drop projects was assessed by comparing the expected revenue to the development cost. Under current electricity market conditions we determined that **9 sites with a total capacity of 0.8 MW were feasible for a payback period of 20 years or less.**

Economically Feasible Ditch Drops within Delta County

Label	Ditch Name	Head (ft)	Flow (cfs)	Estimated Capacity (kW)	Annual Generation (MWh)
D-02	Surface Creek Ditch	130	20.048	188	929
D-03	Surface Creek Ditch	15	18.67	20	99
D-05	Surface Creek Ditch	15	18.756	20	99
D-10	Surface Creek Ditch	45	18.756	61	302
D-11	Surface Creek Ditch	20	16.289	23	114
D-32	Alfalfa Ditch	325	14.763	345	1772
D-45	Highline Ditch	15	22.491	24	105
D-46	Highline Ditch	15	21.534	23	101
D-66	Upper Needle Rock Ditch	160	10.744	124	568



Dam Sites

Results from Analysis

The hydropower potential of existing dams has been explored nationwide by other organizations. These previous studies were used as a starting point for this analysis. There are over 2,000 dams in the State of Colorado, a large number of those dams are very small or only hold water for a very short period of time. The list of dams was narrowed down to exclude dams that were not related to agriculture, on federal lands or were so small that they were very unlikely to hold potential. More detailed and site specific information was collected for the narrowed list of agricultural dams. This more detailed information included actual historical release records and staff gage readings when available.

Five dam sites were identified in Delta County as technically feasible as shown below. These five sites total 542 kW of capacity, and are all individually relatively small (less than 300 kW).

Dam Sites within Delta County

NID ID	Dam Name	Design Head (ft)	Design Flow (cfs)	Estimated Capacity (kW)	Annual Generation (MWh)
CO00639	WARD CREEK	35	3	8	5.5
CO00604	OVERLAND #1	42	50	151	188
UC-22	CRAWFORD DAM	135	31	303	1217
UC-46	FRUITGROWERS DAM	28	17	29	124
CO00629	CARL SMITH	36	20	51	146

Economic Feasibility

None of the five technically-feasible Delta County non-powered dams passed the test for economic feasibility, based on estimated development costs and annual revenue if wholesale power purchase rates remain less than $40 per MWh. The Bureau of Reclamation studied the feasibility of Crawford and Fruitgrowers Dam and found them to have a cost benefit ratio of 0.64 and 0.06 respectively, meaning a hydropower project would generate less revenue than it would cost to develop over 40 years.

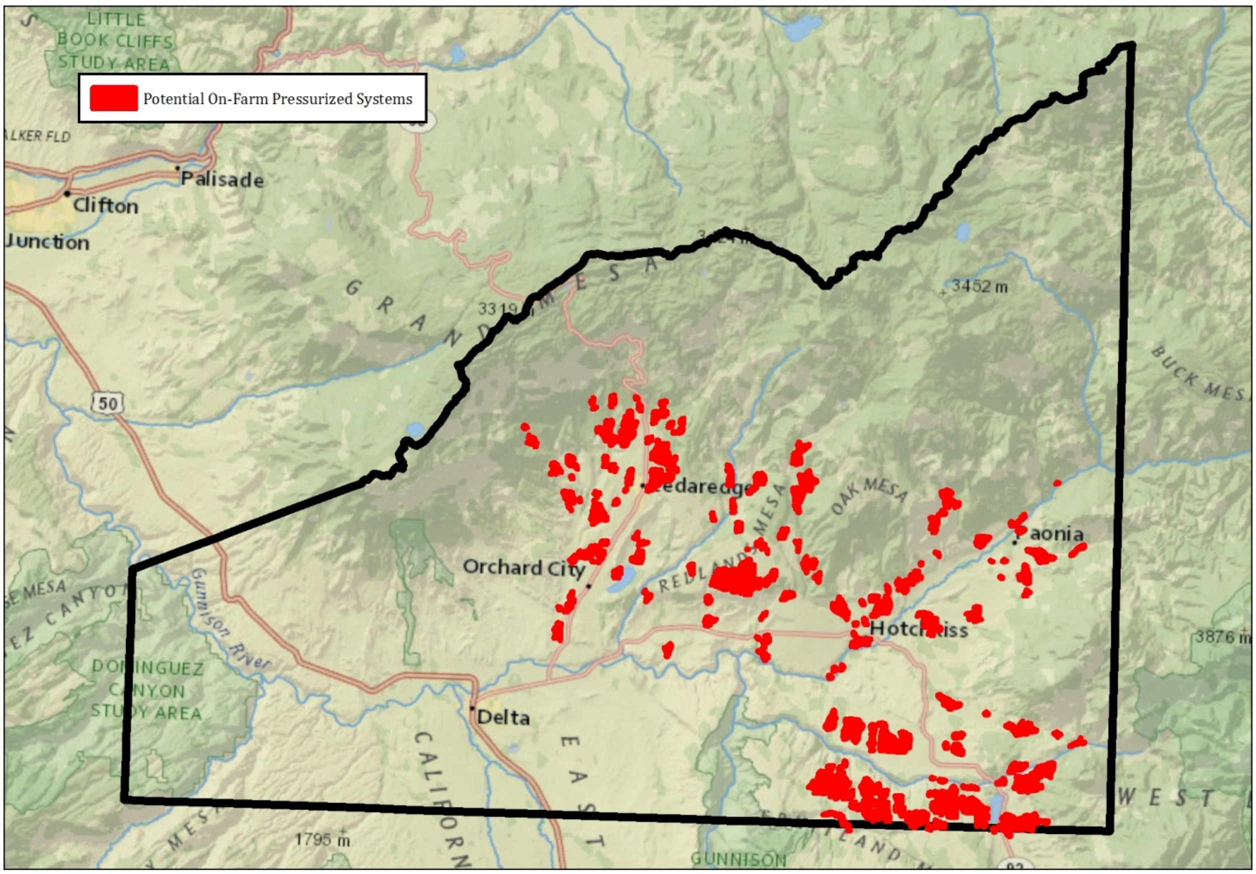
Pressurized Irrigation Systems

Results from Analysis

There is an opportunity to generate hydropower at a gravity pressurized irrigation system, e.g. a center pivot sprinkler, provided that there is either excess flow or excess head available. The pipeline used to deliver irrigation water to the sprinkler system can also provide pressure and water to a hydropower plant. There are several configurations that are possible depending on the amount of excess head and flow available and the proximity of the electrical grid. It may also be possible to retrofit existing center pivots that currently depend on diesel generators or the electrical grid.

According to the CDSS 2005 survey of irrigated lands in Division 4, there are roughly 79,000 acres of land under irrigation in Delta County. Our analysis found that 19% of these lands, or approximately 14,900 acres, are candidates for pressurized irrigation systems. Only 10% of the lands that are candidates for pressurized irrigation system are already sprinkler irrigated; the remaining 90% are predominantly flood or furrow irrigated.

Pressurized Irrigation Sites in Delta County



Economic Feasibility

The power generation potential of all of the lands that are candidates for pressurized irrigation systems (in excess of the power needed to pressurize the irrigation systems themselves) was estimated to be **3.4 MW**. Depending on the situation at a given parcel, this excess power could be used to offset other electrical loads or to mechanically drive the sprinkler system itself.

Given the recent confirmation from NRCS that hydro equipment can be an eligible reimbursable equipment type under the EQIP program (see attached letter), presumably **most of the**

technically feasible sites can also be economically feasible with financial support from NRCS.

Program Recommendations for Delta County

Delta County is well poised to become a leader in development of agricultural hydropower given a supportive local utility (DMEA) and conservation district (Delta Conservation District), well developed data on local hydro opportunities as noted here, and a variety of supportive local organizations (see appendixes) including the U.S. Bureau of Reclamation and USDA. Recommended next steps include the following:

1) Convene an agricultural hydropower meeting
The purpose of the meeting would be to review the data contained in this report and solicit stakeholder suggestions for development of a regional collaborative effort to develop untapped agricultural hydropower potential in Delta County. Likely workshop attendees will include agricultural property owners interested in hydro development, current hydro owners and operators, utilities, environmental organizations, state and local officials, and equipment vendors. It will be important to involve parties who are also tied to the salinity work in the basin, such as the USBR and NRCS. There is a tie between salinity work and hydropower development that if identified in the early stages could potentially benefit both.

2) Develop a Delta County-specific agricultural hydropower action plan. With leadership from the Delta Conservation District, DMEA and others, it may be possible to develop a collaborative local action plan which could effectively leverage the combined resources of local organizations to accelerate development of agricultural hydropower in Delta County. For example, CDA may be able to provide financing to support Delta County project installations in 2014, and the recently announced new USDA loan program (see USDA press release attached below) may be able to provide a loan mechanism in cooperation with DMEA which could support agricultural hydropower project financing.

Appendixes

- Case Study: DMEA South Canal Project
- Case Study: Wenschhof Cattle Ranch Hydro Project
- Case Study: Barton Ranch Hydro Project
- Case Study: Bear River Ranch Hydro-Mechanical Center Pivot Irrigation Project
- NRCS Letter Regarding EQIP Funding for Small Hydro
- Delta County Agricultural Hydro-Related Organizations
- UDSA Press Release
- DMEA Net Metering Policy

Case Study: DMEA South Canal Project

Summary
Located within Delta County, DMEA's South Canal Hydro Project has a combined capacity of 7.5 MM through two separate sites.

Project Overview
The South Canal Hydro Project was completed by DMEA in July 2013. The project's partners were DMEA and Uncompahgre Valley Water Users Association. The project was permitted through USBR's Lease of Power Privilege process. The project was financed through Clean Renewable Energy Bonds (CREBs). The South Canal project has a current combined capacity of 7.5 MW, through two separate sites. The project had a budget of $22 million, which included all hydro facilities, power lines and substations.

Source: COSHA Website, DMEA Presentation from July 2013 COSHA Conference

Case Study: Wenschhof Cattle Ranch Hydro Project

Summary
George Wenschhof, a cattle rancher in Meeker, Colo., figured out how to harness the mechanical energy in his center pivot sprinkler irrigation system to power his ranch through installation of a 23-kW hydropower plant from Canyon Hydro. Wenschhof installed a hydroelectric generator to offset the electrical load of his irrigation system and all of his ranch operations. A case study from the Colorado Energy Office notes that the project is saving $10,000 to $13,000 per year in avoided electric bills.

Project Overview
George Wenschhof, a rancher in Meeker, Colorado and the owner and operator of the Wenschhof Cattle Company, participated in the Natural Resources Conservation Services (NRCS) Environmental Quality Incentives Program (EQIP) to convert his irrigation from flood to a sprinkler system. He installed a large center pivot sprinkler system as well as a small hydroelectric generating facility. The turbine will produce enough power to offset the electrical demands of the center pivot and all ranch operations.

Project Components
The project included the following components:
- An improved intake and screen at the Miller Creek Ditch.
- Pipeline that feeds both the center pivot sprinkler and the hydroelectric turbine.
- A 23 kW double nozzle Pelton Turbine and induction generator with all associated controls.
- An extension of the three phase power to the power house.
- A power house to house the turbine, generator and controls.
- A discharge basin below the power house, with a small pump that can be used to irrigate

Project Conclusions
The project proved to be economically favorable. Mr. Wenschhof was able to utilize the infrastructure put in place for the center pivot to also benefit the hydropower facility. The NRCS assisted the project with funding towards the turbine itself. By only producing enough electricity to offset the demands of the ranch, the value of the electricity produced is the retail rate of close to11 cents/kWh. This project will save the ranch approximately $10,000 - $13,000 per year in electrical bills. Center pivot sprinkler systems consume a large amount of energy; incorporating a hydroelectric turbine in a center pivot project can make the entire project more cost effective.

Source: Flux Farm Foundation, July 2011

Case Study: Barton Ranch Hydro Project

Roger and Shelley Barton own and operate Barton Farm in Ferron, Utah. The Bartons farm 120 acres of alfalfa and mixed grasses used for horse hay. They irrigate with a center-pivot irrigation system. Diesel fuel is a large expense in operating a center pivot. The Bartons needed to reduce fuel costs and still follow their irrigation schedule.

The Barton's hay fields are located a half-mile from the nearest overhead power line. After considering the cost to have single-phase power run to the field, the Barton's selected a T-L diesel-powered hydraulic center-pivot irrigation system and had it installed in 1998. This T-L hydraulic center pivot is powered by a diesel motor and uses gravity flow to pressurize the irrigation system. A small DC alternator operates the control panel. At the time the irrigation system was installed, the national average cost for diesel hovered at around $1 a gallon. In 2008, the Bartons paid $4.25 a gallon. Fuel costs for the irrigation system were about $4,000 a year and rising.

Roger Barton has eliminated all irrigation fuel costs by integrating a hydro turbine into his existing center pivot. Photo by Roger Barton.

The Bartons met with Ken Gardner, a civil engineer and hydropower specialist with Gardner Engineering, to consider alternative energy options to power their system. They determined that the irrigation system required only about 53 percent of the available water pressure. The additional pressure could be used to power the turbine. The Bartons could keep their existing irrigation system and reduce their fuel costs to zero.

Siting and Layout Considerations

The combination of a hydraulic center pivot and hydro turbine are generally a good match when available pressure exceeds the requirements of the irrigation system by 40 pounds per square inch (PSI) or more. The Bartons receive irrigation water by gravity feed from a reservoir several miles away, which provided 80 PSI of operating pressure at the pivot point, 37 PSI more than required to operate 1,220 feet of pivot and the end gun. The T-L hydraulic pivot installed at the Bartons requires 15 horsepower (HP) to operate correctly.

The Bartons hired Redmond Irrigation in Redmond, Utah to design and install the system. A Cornell turbine from Centex Fluid Products was selected. Centex designs and sells custom hydro turbines, made by Cornell Pump Company, that work with a range of heads, flows and pressures. The basic method of sizing this system included: assessing the flow (the volume of water passing through the pipe), determining the residual (additional) pressure available, calculating any pipe or other head and flow losses and evaluating the technical requirements of the irrigation system. This data was provided to Centex to design the turbine.

Gate valves on the incoming line and discharge allow flow to be incrementally adjusted if necessary and shut the system off for maintenance. Photo by Roger Barton

The Cornell hydro turbine was coupled with the T-L variable-displacement hydraulic pump using a belt drive. The system is monitored by the T-L control system. A filter was installed before the turbine to remove sand, gravel and other water debris that can damage the turbine impeller. Auto valves with a trip switch automatically shut down flow to the turbine if there is a problem in the system. An integrated 12-volt alternator provides the DC voltage required by the control panel.

Financial Incentives

The cost for design, equipment and installation of this system was $17,000. The Bartons received a $4,000 cost share under the NRCS Conservation Innovation Grant program. The estimated simple payback on the hydro turbine system is 2.5 to three years. In Utah, NRCS is currently offering a 65 percent cost share for this type of system under the Environmental Quality Incentives Program (EQIP).

System Specifications

- Hydro resource: Gravity flow from reservoir
- Total pressure: 80 PSI
- Additional pressure: 37 PSI
- Head: 162 ft
- Flow: 888 gpm
- Irrigation system: T-L hydrostatic center pivot
- Hydro turbine: Cornell Turbine (5TR5-F16)
- Runner type: Francis
- Pipe: 10 inch steel w/ compression fittings
- Total System Cost: $17,000 (before cost share)
- Incentives: $4,000
- Cost savings estimate: $4,000 annually
- Simple payback estimate: 4 years

"One disadvantage we discovered," said Barton "is that water must be running through the turbine to move the pivot." The T-L hydraulic pivot continuously "walks" as long as the turbine is operating. "If you are crossing ground you do not want to irrigate, you may want to install a backup diesel motor in addition to the hydro system", said Barton. Re-nozzling of the pivot may also be necessary to compensate for the reduction in pressure throughout the system.

Roger Barton says farmers and ranchers should be in contact with a knowledgeable consultant early on to determine if they have enough pressure to integrate a hydro turbine. "Once the resource is determined to be sufficient, look at how to reduce the system costs", said Barton. NRCS offers a cost share and the Rural Energy for America Program (REAP) provides grants, through USDA Rural Development.

An integrated hydro turbine with a gravity-flow irrigation system is an excellent opportunity to reduce fuel costs. These systems are simpler than hydro-electric systems. The consistent flow and pressure of a gravity-flow hydro resource allow the turbine to be designed for the specific resource and require very few adjustments down the road.

Source: Hydro Power for Gravity Flow Irrigation Systems
By Leif Kindberg, ATTRA Farm Energy Specialist, May 2010

Case Study: Bear River Ranch Hydro-Mechanical Center Pivot Irrigation Project

Summary

When confronted with rising water costs and low crop yields, Bear River Ranch, located near Steamboat Springs, installed a hydro-mechanical system to power its center-pivot irrigation system. This system uses the power of falling water to directly drive and pressurize the center pivot; this eliminates the need for electricity and significantly reduces operating expenses. The turbine uses 126 feet of head and 560 gpm to produce the equivalent of 5.2 kW of power which drives the center pivot. The $13,000 project was funded through $6000 in support from NRCS, yielding out of pocket cost to the ranch of$7000 and an expected payback of slightly over 3 years.

Background

The Natural Resource Conservation Service (NRCS) encourages water conservation by supporting the conversion of flood irrigation to sprinklers and also supports renewable energy for on-farm applications. By working with the NRCS for project design and financial assistance, Bear River Ranch was able to achieve both NRCS goals. A center pivot sprinkler was chosen as the water conservation measure, which uses significantly less water than the previous method of flood irrigation. A hydro-mechanical system was installed to eliminate the energy required to power the center pivot.

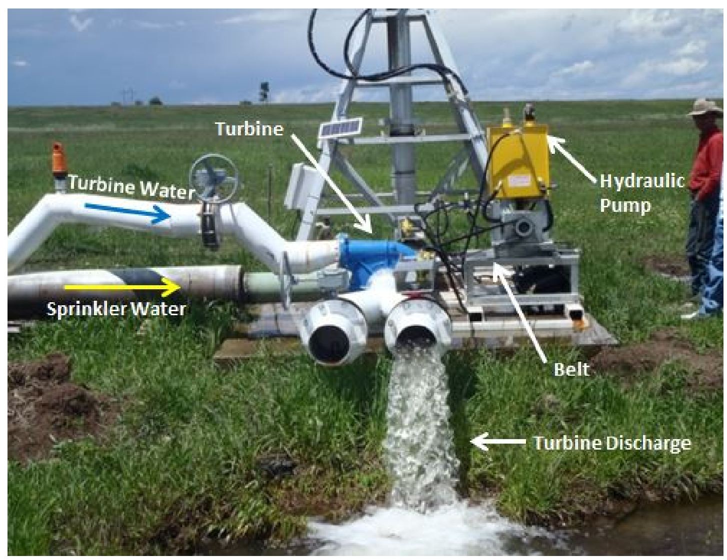


Figure 1. Key components of the Hydro-Mechanical Irrigation System

Design and Technical Details

The photograph at right shows the key components of the system: a turbine that powers the hydraulic pump through use of a connecting belt, and water supply lines to power the turbine and provide water to the sprinklers. A single, supply pipeline originates from a settling pond at a point 150 feet higher in elevation. This elevation difference pressurizes the water in the pipeline. Just before reaching the center pivot, the pipeline splits into two smaller supply pipes as shown in Figure 1; the pressurized water powers the turbine (via the pipe denoted with a blue arrow) and supplies the sprinklers (via the pipe denoted with a yellow arrow). The turbine is attached to a shaft which drives a belt connected to the hydraulic pump. The hydraulic pump powers the drive system that moves the center pivot wheels and turns the sprinkler system.

Hydro-mechanical systems are relatively simple, so complex safety and operational procedures are typically not necessary. Because the use of hydro-mechanical systems is relatively rare, a lack of institutional knowledge has prevented their widespread use to date.

The Bear River Ranch turbine produces an equivalent of 5.2 kW or 7 HP to power the hydraulic pump on the center pivot sprinkler system. The hydraulic pump powers the drive system that turns the sprinkler, and the sprinkler is pressurized through gravity. No pumps, motors or electrical connections are required, resulting in very low annual operational expenses and minimal maintenance. Because it does not produce electricity, the project is not regulated by the Federal Energy Regulatory Commission.

The center pivot is operated only during irrigation season, with operation dictated by the crop's water demand. A T-L Irrigation hydrostatic center pivot with manual speed control was selected for the sprinkler system and a Cornell Pump (5TR5) was selected as the turbine. Cornell pumps are easily obtainable due to their dual purpose. Most pumps can be used for both pumping and as a turbine without any modification.

Construction of the hydro-mechanical system was a fast and simple process, spanning only one non-irrigation season. The center pivot distributor, B&B Irrigation, consulted with Jordan Whittaker of Two Dot Irrigation to select the turbine and design the connection. Because the turbine and hydraulic pump are belted together, their power outputs are essentially equivalent. As such, the turbine was sized to provide 7 HP or 5.2 kW which corresponds to the power needed for proper operation of the hydraulic pump. The turbine uses a flow of 560 gpm at the available 126 feet of working head to provide the 7 HP to the hydraulic pump.

Maintenance of the system is very simple. The turbine will need to be maintained as a pump would, with occasional bearing greasing. The center pivot machinery and turbine are generally given a useful lifetime of 20 years, although with proper operation and maintenance, they can last much longer. Premature wear due to debris and sediment in the water is possible and could reduce the expected lifespan of the turbine so care must be taken to adequately filter the water prior to its entry into the system.

Economics

NRCS support the project in both the design of the irrigation system and partial funding of the entire project through the Environmental Quality Incentives Program (EQIP) program. EQIP provides financial and technical assistance to farmers and ranchers for the planning and implementation of natural resource conservation efforts. During 2011, EQIP allocated over $26 million for nearly 800 projects in Colorado. For Bear River Ranch, the NRCS grant lowered installation costs enough to make NRCS the only outside source of funding needed.

The only cost incurred which varied from that of a traditional, electricity-driven center pivot is that of the turbine; the center pivot sprinkler and pipeline costs were equivalent to traditional center pivot installations. The purchase of the turbine amounted to $13,000 to which the NRCS contributed $6,000, making the out-of-pocket expense for the system $7,000. The system saves estimated annual energy costs of approximately $2,100. Power to spin to the center pivot could alternatively have been obtained through either a diesel generator or grid interconnection if Bear River Ranch had opted for a traditional center pivot irrigation system, but this would result in annual fuel/electricity expenses. If electricity had been extended to the center pivot location, it would have cost $22,000. Center pivot systems using diesel or electricity would have higher installation costs and would have resulted in higher annual expenses. With the hydro-mechanical system, the initial investment by the ranch of $7,000 will be recaptured in 3.3 years of energy savings.

Lessons Learned

The project ran successfully through the 2012 irrigation season with no problems reported and increased crop yields using less water than had historically been used with flood irrigation. Many of the ranchers in the area are expressing an interest in installing the same type of system. Some have submitted applications to the local NRCS office, which is hoping to offer design services for this type of system. Such a system can potentially be replicated throughout Colorado in areas where sufficient pressure can be generated using at least 100 to 150 feet of fall.

Source: Colorado Energy Office, June 2013

NRCS Letter Regarding EQIP Funding for Small Hydro

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
Denver Federal Center
Building 56, Room 2604
P.O. Box 25426
Denver, CO 80225

November 19, 2013

Kurt Johnson
Colorado Small Hydro Association
P.O. Box 1646
Telluride, CO 81435

Dear Mr. Johnson:

Thank you for your letter of November 5, 2013, regarding the Natural Resources Conservation Service (NRCS) in Colorado providing financial assistance through the Environmental Quality Incentives Program (EQIP) to help producers install micro-hydro components as part of irrigation system improvements. You requested consideration for inclusion of language in the pending Farm Bill discussion to ensure that NRCS had authority through EQIP to support these micro-hydro components.

I am happy to report that NRCS national program leadership has confirmed that sufficient authority currently exists through EQIP to support micro-hydro components. This reimbursement will be made when the component is included as part of a center pivot or other irrigation system improvements addressing water quantity concerns. Unfortunately, the components were not included in the payment schedules for FY 2014 and therefore will not be available this year.

We will be working with our EQIP program managers to ensure that the costs of such devices are included in our EQIP financial assistance practice payments at the earliest possible opportunity and will be available for FY 2015.

I appreciate you bringing this to our attention. Thank you for your commitment in helping agricultural producers address resource opportunities and important energy issues. If you have any questions, please feel free to contact me.

PHYLLIS ANN PHILIPPS
State Conservationist

cc:
Michael Bennet, Senator, U.S. Congress, 835 E. 2nd Ave., Suite 206, Durango, CO 81301
Jason Weller, Chief, NRCS, Washington, DC
Astor Boozer, Regional Conservationist – West, Washington, DC
Wayne Honeycutt, Deputy Chief for Science and Technology, NRCS, Washington, DC
Anthony Kramer, Deputy Chief for Programs, NRCS, Washington, DC

Helping People Help the Land

Delta County Agricultural Hydro-Related Organizations

U.S. Bureau of Reclamation

The U.S. Bureau of Reclamation developed Fire Mountain Canal, which provides water from Paonia Reservoir to agricultural producers throughout the region.

Contact
Dan Crabtree
Water Management Group Chief
U.S. Bureau of Reclamation
970-248-0652
dcrabtree@usbr.gov

Delta Conservation District

The mission of the Delta Conservation District is to provide for the conservation and preservation of our natural resources and agricultural heritage in order to ensure the health, prosperity and welfare of the citizens of the District and the State of Colorado.

Contact
Dev Carey, Manager
Delta Conservation District
690 Industrial Blvd
Delta, Colorado 81416
970-874-5726
Website: http://deltacd.net/
David.carey@co.nacdnet.net

Delta Montrose Electric Association (DMEA)

DMEA recently completed the South Canal hydro project, a 7.5 MW small hydro project. DMEA has preliminarily indicated a willingness to support development of an agricultural hydropower pilot project in Delta County.

Contact
Jim Heneghan, Renewable Energy Engineer
DMEA
11925 6300 Road
Montrose, CO 81401
jim.heneghan@dmea.com
970-240-1269

Solar Energy International (SEI).

Solar Energy International, located in Paonia, is a training organization which provides hands on renewable energy training in micro-hydro system construction, including an annual weeklong spring class which typically includes hands-on site feasibility assessments.

<u>Contact</u>
Kathy Swartz, Executive Director
39845 Mathews Lane
Paonia, CO 81428
<u>kswartz@solarenergy.org</u>
970-963-8855

USDA Press Release

USDA News Release No. 0228.13
Contact: USDA Office of Communications (202) 720-4623

Agriculture Secretary Vilsack Announces Energy Efficiency Loan Program to Lower Costs for Consumers, Reduce Greenhouse Gas Emissions

Rural Development Loan Program is Latest USDA Effort in Support of Climate Action Plan

WASHINGTON, Dec. 4, 2013 – Agriculture Secretary Tom Vilsack today announced that USDA will take new steps to save consumers money on their energy bills in partnership with rural electric cooperatives. USDA plans to provide rural electric cooperatives up to $250 million to lend to business and residential customers for energy efficiency improvements and renewable energy systems.

"Energy efficiency retrofitting can shrink home energy use by 40 percent, saving money for consumers and helping rural utilities manage their electric load more efficiently," said Vilsack. "Ultimately, reducing energy use helps pump capital back into rural communities. This program is designed to meet the unique needs of consumers and businesses to encourage energy efficiency retrofitting projects across rural America."

Vilsack noted that the Energy Efficiency and Loan Conservation Program, by promoting energy savings in rural areas, is another step by which USDA is supporting President Obama's Climate Action Plan. The program will help build a cleaner and more sustainable domestic energy sector for future generations by reducing barriers to investment in energy efficiency and potentially cutting energy bills for American families and businesses in the process.

Although energy efficiency measures can reduce home energy use considerably, many consumers and businesses do not invest in them because they lack the capital or financing to do so. Consistent with President Obama's Climate Action Plan, this program will reduce barriers to these investments by making financing more available.

Funding will be provided to rural electric cooperatives and utilities – the majority of which already have energy efficiency programs in place – who will then re-lend the money to help homeowners or businesses make energy efficiency improvements. In addition to energy audits, the loans may be used for upgrades to heating, lighting and insulation, and conversions to more efficient or renewable energy sources.

A March 2012 Rockefeller Foundation report on financing energy efficiency projects found that a $279 billion investment could yield more than $1 trillion in energy savings over 10 years. That is the equivalent of 30 percent of the annual electricity spending in the U.S. Funding from the loan program will complement and strengthen other energy efficiency activities at USDA. Through its Rural Development mission area, USDA also supports the research, development and use of renewable fuels.

Vilsack noted that many of USDA's existing efforts to promote renewable energy and energy efficiency are provided by the Farm Bill – and he once again urged Congress to provide a new, multiyear Food, Farm and Jobs Bill that continues investing in a clean energy future for rural America.

The rule is scheduled to publish in the Dec. 5 issue of the Federal Register.
President Obama's plan for rural America has brought about historic investment and resulted in stronger rural communities. Under the President's leadership, these investments in housing, community facilities, businesses and infrastructure have empowered rural America to continue leading the way – strengthening America's economy, small towns and rural communities. USDA's investments in rural communities support the rural way of life that stands as the backbone of our American values.

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DMEA Net Metering Policy

DMEA	DELTA-MONTROSE ELECTRIC ASSOCIATION BOARD OF DIRECTORS POLICY NET METERING	BP 18 Sections 1-9
Subject: Net Metering		Page 1 of 3
Last Revised: 02/22/2011	Last Reviewed: 02/22/2011	Board Approval: 02/22/2011

OBJECTIVE

To encourage our members to install solar, wind, hydro, and similar renewable generation facilities to fulfill or partially fulfill their own electrical requirements and to set the standards and limitations under which DMEA will allow members to interconnect to the electric grid within DMEA's service territory for net metering purposes.

ACCOUNTABILITY

The General Manager and key management personnel

SCOPE

Section 1. APPLICABILITY:

Applicable to renewable electric generation (photovoltaic, hydroelectric, and wind) facilities up to 25 kilowatts (25 kW) – (nameplate aggregate of all technologies at a single metered location) that are interconnected on the member side of the DMEA electric meter and operating in parallel with the electric grid. Any interconnection not meeting this applicability shall be subject to PURPA interconnections or other applicable agencies having jurisdiction.

Renewable electric generation facilities which exceed 25 kilowatts (nameplate aggregate of all technologies at a single metered location) may be interconnected under the following criteria

1. Approval from Tri-State Generation and Transmission
2. Maximum nameplate aggregate of all technologies as listed below
   a. Large Commercial 250 kW
   b. Small Commercial 50 kW

Section 2. CONDITIONS OF SERVICE:

1. Interconnections of Renewable Systems are limited in size by the lesser of two amounts:
   a. 25 kW nameplate rating
   a. Nameplate rating of the transformer interconnected through.

DMEA	DELTA-MONTROSE ELECTRIC ASSOCIATION BOARD OF DIRECTORS POLICY NET METERING	BP 18 Sections 1-9
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2. Rebates may be made available toward installation cost pursuant to discretion of the Board of Directors. To be eligible for rebates, capacity rights or "Green Tags" must be transferred to DMEA, if available.
3. Credits will accrue to the account when generation exceeds usage. If member disconnects with a credit balance, said credits will be forfeited to DMEA. Credits cannot be transferred from account. No "payments" will be made to the member.
4. Interconnection with DMEA shall be at standard available voltages and connections. Total Harmonic Distortion (THD) shall be less than 5%.
5. Applications under this policy must be made in writing.
6. Rates will be based upon existing rate tariffs.

Section 3. TERM:

This renewable interconnection policy may be revised periodically and is subject to change and/or termination at the discretion of the Board of Directors of Delta-Montrose Electric Association.

Section 4. METERING:

PV systems meeting all applicable codes, policies, and certifications require a single, net meter only. This meter will be installed by DMEA and replace the existing DMEA meter.

Other renewable energy systems may require a second meter base to allow metering of generation output. Contact DMEA prior to installation.

Section 5. INTERCONNECTION STANDARDS AND SAFETY:

To be eligible, the customer's system must meet all applicable current National Electrical Codes, the Institute of Electrical and Electronic Engineers and other accredited testing laboratories such as Underwriter's Laboratories. Any safety hazard shall be subject to immediate disconnection by DMEA.

Section 6. EVENTS WHICH MAY REQUIRE DISCONNECTION:

Unsafe conditions and any condition determined by DMEA to be in the best interests of safety to the public or employees.

DMEA	DELTA-MONTROSE ELECTRIC ASSOCIATION BOARD OF DIRECTORS POLICY NET METERING	BP 18 Sections 1-9
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Section 7. PAYMENT:

Energy credits may accrue indefinitely however, no cash credit will be paid.

Section 8. ADMINISTRATIVE FEE:

None

Section 9. Rate Schedules:

Res NM rate schedules will be used to designate the net metering status of residential accounts. All other accounts will have "NM" added to the existing rate schedule to indicate the net metering status of the account.

Appendix H: Colorado Agricultural Hydropower Potential

Available Data

There is a wealth of available data regarding existing irrigation, topography, hydrography, and hydropower potential. This data is not entirely complete for the analysis proposed in this study. The data, sources and content are summarized in this section. The next section discusses the methodology used to develop the additional data and where data is not available or cannot be created without significant effort outside of the scope of this study.

Delta Conservation District GIS Data

In 2011, the Delta Conservation District initiated an effort to collect information on the amount of unlined earthen ditches and laterals in the Delta Conservation District and to map the locations of ditches with over 4 cfs of deeded water rights and more than one land owner using a handheld GPS unit. This work resulted in a dataset showing the ditch alignments, headgate locations, typical flows at different locations throughout each ditch, and other information, which was published in January 2012. This dataset offers a more complete survey of irrigation conduits within Delta County than is available from national level datasets. Critically, it provides estimates of flows at various locations within each system, something that is lacking in other datasets of irrigation conduits.

Some improvements could still be made in the ways the data was collected and presented which, if observed, could benefit future collection efforts elsewhere. The following suggestions would have made the dataset more useful in terms of identifying hydropower opportunities:

- **Single Shapefile**: Each individual ditch alignment was contained in its own separate shapefile. The information would be much easier to manage and evaluate if all of the ditch alignments were contained in a single shapefile or dataset.
- **Consistent Attribute Fields**: the names and data types for the shapefile attribute fields were not consistent across all of the ditches, making it difficult to merge individual shapefiles together. It would be better to adopt a consistent attribute field name and data type convention in the beginning for all shapefiles. Alternatively, using a single shapefile for the ditch alignments (as previously suggested) would automatically solve this issue.
- **CDSS Cross-Referencing**: We recommend assigning the Colorado Decision Support System (CDSS) water district structure ID number ("WDID") to each ditch alignment to allow easy cross-referencing with the multitude of additional data maintained by CDSS.
- **Alignment Connectivity**: Individual segments of a ditch alignment were not always connected together. The data would be easier to manage if the endpoints of individual segments were "snapped" together, thus allowing the entire ditch alignment to be merged into a single line if needed. Single-line alignments are useful when calculating the surface profile of the ditch.
- **Shareholder Identification**: Shareholders served at headgates were identified by name. The information provided was not adequate to quickly relate headgate locations to parcels or irrigated lands. An improvement would be to associate headgate locations with the

CDSS parcel ID of the irrigated field that headgate serves. Alternatively, the headgate could be associated with the parcel ID of the County parcel served by the headgate.

Delta-Montrose Electric Association Transmission Line Data

Delta County electric meter and transformer data was procured from the Delta-Montrose Electric Association (DMEA). The data was used to estimate distances from potential hydropower sites identified in this study to the nearest existing electrical service, allowing a more accurate development cost estimate.

Oak Ridge National Laboratory 2012 Non-Powered Dam Study

In 2012, Oak Ridge National Laboratory (ORNL) compiled a comprehensive list of over 84,000 Non-Powered Dams existing in the U.S., with over 54,000 with hydropower potential. Within that assessment, 1,204 sites with hydropower potential were located within Colorado, totaling an estimated 171.6 MW, or 540,694 MWh/year. ORNL highly recommend further evaluation and quality control since most of these sites have relatively small potential and the capacity estimation methodology yields potentially unrealistically high capacity and energy estimates.

Through ORNL's assessment, the data below were collected for each dam evaluated in this study:

- The official NID identification number for the dam, known formerly as the National ID. This field is used as the unique identifier for each dam record. The first two characters of the identity are the state two-letter abbreviation, based on the location of the dam. The last five characters of the identity are a unique number.
- Latitude and Longitude, with the coordinate's sources from either the National Inventory of Dams or the National Hydrology Dataset.
- Official name of the Dam
- Name of the dam owner
- State, county, and nearest city, town or village that is most likely to be affected by floods resulting from the failure of the dam.
- Year when the original main dam was completed.
- A calculated field based on the maximum value of Maximum Storage and Normal storage. Maximum storage, in acre-feet, which is defined as the total storage space in a reservoir below the maximum attainable water surface elevation, including any surcharge storage. Normal storage, in acre-feet, which is defined as the total storage space in a reservoir below the normal retention level, including dead and inactive storage and excluding any flood control or surcharge storage.
- Federal Agency Involvement in Regulation
- Estimated head (ft) available for hydropower generation, and source of head estimate.
- Watershed Boundary Dataset
- Estimated Flow, broken down by annual mean flow and each month's mean flow.
- Potential Annual Hydropower Energy (MWh), a product of estimated flow (cfs), head (ft), efficiency (0.85), time (hr), and broken down by monthly potential generation.

- Potential Capacity (MW).

United States Bureau of Reclamation 2011 Hydropower Resource Assessment at Existing Reclamation Facilities

In 2011, the United States Bureau of Reclamation (USBR) published a Hydropower Resource Assessment at Existing Reclamation Facilities which evaluated the development potential of hydropower projects at reclamation-owned facilities. Additionally, the report provides information on whether hydropower development at existing reclamation facilities could be economically viable and therefore possibly warrant further investigation. Potential existing sites are broken down by region, including the Upper Colorado region, where there are 65 sites listed. Many of the sites listed in USBR's data overlap with ORNL's data set.

Data collected through USBR's assessment included the following:

- Region
- Site name/facility
- Design head
- Design flow
- Estimated installed capacity (kW)
- Annual production (MWh)
- Plant factor
- Total construction costs
- Annual operating and maintenance costs
- Benefit cost ration with green incentives
- Internal Rate of Return (IRR) with green incentives
- Benefit cost ration without green incentives
- IRR without green incentives

United States Bureau of Reclamation 2012 Hydropower Energy Assessment of Reclamation Owned Conduits

In 2012, the USBR published a Hydropower Energy Assessment of Reclamation Owned Conduits which evaluated the development potential of hydropower projects on Reclamation owned conduits. This study did not investigate the economic viability of the various sites. A total of 51 sites in Colorado were identified, with 23 of those sites removed from further consideration primarily due to a lack of usable head or flow at the locations.
Data collected through this USBR assessment included the following:

- Canal Site Name
- Project
- State
- Structure Type
- Potential installed capacity (kW)
- Potential Annual Energy (kWh)
- Design Head (ft)

- Max Turbine Flow (cfs)
- Plant Factor
- Months of Potential Generation
- Closest Distribution or Transmission Line (miles)
- Available flow data frequency (i.e. daily, monthly, seasonal, etc.)

National Hydrography Dataset (NHD)

The National Hydrography Dataset (NHD) is the surface water component of the National Map developed by the United States Geological Survey. The NHD is a digital vector dataset used by geographic information systems (GIS). It contains features such as lakes, ponds, streams, rivers, canals, dams and streamgages. These data are designed to be used in general mapping and in the analysis of surface-water systems. Of primary interest to this study were the alignment of manmade ditches and canals. These alignments are contained in the NHD Flowline layer, where most ditches and canals are coded with an FType value of 336 ("CanalDitch"). However, some major canals throughout the state were coded with an FType value of 558 ("ArtificalPath"). These canals were manually identified to ensure they were included in the analysis (http://nhd.usgs.gov/).

National Elevation Dataset (NED)

The United States Geological Survey developed the National Elevation Database (NED), which is a seamless mosaic of best-available elevation data. This data is available for download through the National Map. The entire State of Colorado is covered by NED data at 1/3 arc-second resolution (approximately 10 meter grid spacing). This product is used to provide elevation information for the analysis. (http://nationalmap.gov/)

Colorado State University (CSU) Ditch Drop Study

The intent of this study was to determine whether drops on conduits could be identified using existing GIS data. Field visits to various sites were conducted by Brian Campbell, information such as location, type and head were collected. This data set includes 260 existing structures and does overlap with some of the USBR data. The feasibility of developing these sites was not evaluated; these drops were simply identified, measured and located.

Colorado Decision Support System (CDSS) Irrigated Lands

Colorado's Decision Support Systems (CDSS) is a water management system developed by the Colorado Water Conservation Board (CWCB) and the Colorado Division of Water Resources (DWR) for each of Colorado's major water basins. Hydrobase data available through the CDSS includes irrigated acreage for various years. The data that is available depends on the Department of Water Resources Division, and may vary by the years available. This study will use the most recent data for each division, which corresponds to 2005 for Divisions 1, 4, 5, 6, & 7 and 2010 for Division 3. For Division 2, unpublished draft irrigated land data was provided by CDSS for use in this study.

United States Census Bureau Tiger/Line Road Data

The United States Census Bureau provides road alignment data created through the Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) database of geographic information. The data is coded by road type, ranging from large interstates through small vehicular trails. Because electrical transmission/distribution line data is not available statewide, road data was investigated as a proxy for estimating distances from potential hydropower sites to transmission/distribution lines under the assumption that transmission/distribution lines would be near major roads. For this study, major roads were defined as FCC codes of A1 (primary highways with limited access) through A4 (local, neighborhood, and rural roads).

Non-Powered Dam Sites Evaluation

Existing non-powered dams located in Colorado were investigated to determine their hydropower potential.

Gaps and Methodology for Narrowing Target List

In filtering out sites from ORNL and USBR's data to match with agriculture-related hydro sites that could be economically feasible, several filtering parameters were applied:

- Remove dams with storage equal to zero.
- Remove dams by owner names which clearly indicate no ties to agriculture (e.g. municipalities, etc.)
- Remove dams with height of less than 10 feet.
- Remove dams with less than 100 ac-feet of storage that are identified as being off channel ("-OS").
- Removed dams with less than 10kW capacity as estimated by ONRL, but only those with less than 30 feet of head and less than 1,000 acre-feet of storage.

This initial filtering process resulted in 222 dams.

The ORNL assessment of hydrologic conditions is based on natural rainfall and drainage basins and does not take into account regulation from upstream reservoirs, diversions, contributions from transmountain diversions or canals. For this reason, we are reassessing the flow available at specific sites. However, there are some assumptions that can be made about the available flow based on the ORNL Hydrology, particularly for the very small dams.

There is a lower limit on the capacity of a hydropower facility that is economically feasible on a non-powered dam.

Connecting hydropower to a dam outlet is a significant undertaking and will not be economically feasible for a very small capacity. As an initial filtering on feasible sites, we considered that the very small sites will need to utilize a commercially available, "off the shelf" turbine, especially for low head sites. Building a custom turbine for a site with less than 50 feet of head and less than 50 cfs (less than 200 kW) is not likely to be economically feasible. In this range a custom turbine would be utilized. Custom turbines have their limitations on the range of head and flow which they operate under optimal conditions. There are a few turbines (Mavel and Natel) that will operate at 20 feet of head and less than 50 cfs, but under this range the option for turbines is very limited.

To filter the 222 remaining dams, we used these criteria, because of the likely infeasibility of a project at the site. This filtering was done prior to an in depth analysis of flows and used the ORNL hydrology estimate (the max average monthly flow rate). The hydrologic data may be incorrect due to the reasons stated above, but we do not believe that the actual flow would exceed the natural maximum flow estimated. One exception to this is a large off channel reservoir that is filled by a canal; in this case the canal flow could contribute significantly to the outflow. Dams with less than 20 feet of head and a maximum monthly average flow of less than 50 cfs were removed from further consideration due to unlikely economic feasibility.

Considering flow, the smallest off the shelf turbine that can operate with less than 50 feet of head will need at least 8.8 cfs to operate. Therefore sites with less than 50 feet of head and less than 8.8 cfs of flow (maximum monthly) have been removed from further consideration.

The filtered dams were individually assessed to see if they fall within the exception to the statement above. If a canal was feeding the reservoir, the dam was left on the list. In using the above filters and parameters, the remaining list includes 115 existing dams.

<u>Design Data for Dams</u>

Data obtained through the Colorado Decision Support System (CDSS) provides historical daily (cfs) or monthly (acre-feet) diversion data and general water-rights information for structures such as ditches, reservoirs, and wells throughout Colorado, including those listed in ORNL's assessment. Typically, this website is used to download diversion data (annual in acre-feet or daily in cfs) for a specific point of diversion, choose detailed diversion coding when researching specific diversion types (e.g., irrigation vs. municipal) at a point of diversion, and find general water rights information for a point of diversion, e.g., diversion type or decreed rate.

To search the CDSS database, several different parameters can be used, including structure ID, structure name, water source, legal location, decreed amounts, or owner name; however, the best way to search the site is by using the CDSS map data, and then determine the name of the structure as used by CDSS. This task was done by (1) converting the latitude and longitude coordinates provided by ORNL for each facility into UTM coordinates and subsequently (2) using the search tool within the CDSS mapping features to identify the sites.

These steps can also be used to identify any gages in the vicinity which could be used to obtain flow or elevation data in the event the CDSS release data is incomplete. However, useful gage data was not found using CDSS for the structures of interest.

For each site returned on the search, the below data points are provided:

- Structure ID
- District number (WD) and Stricture ID number, or combined WDID numbers.
- The "WDID" number is a combination of the District number (WD) and the Structure ID. In the case where the structure ID is only three digits, add a zero to the front to make it four digits long.
- Structure Name
- Section, township
- Year
- Daily cfs releases
- Monthly acre-feet releases
- Annual acre-feet releases
- In some cases, height of reservoir data is available on a monthly basis (ft)

By reviewing data provided in the CDSS documentation, some dams from the list were identified as having zero potential for various reasons. These dams were removed and added to the filtered list.

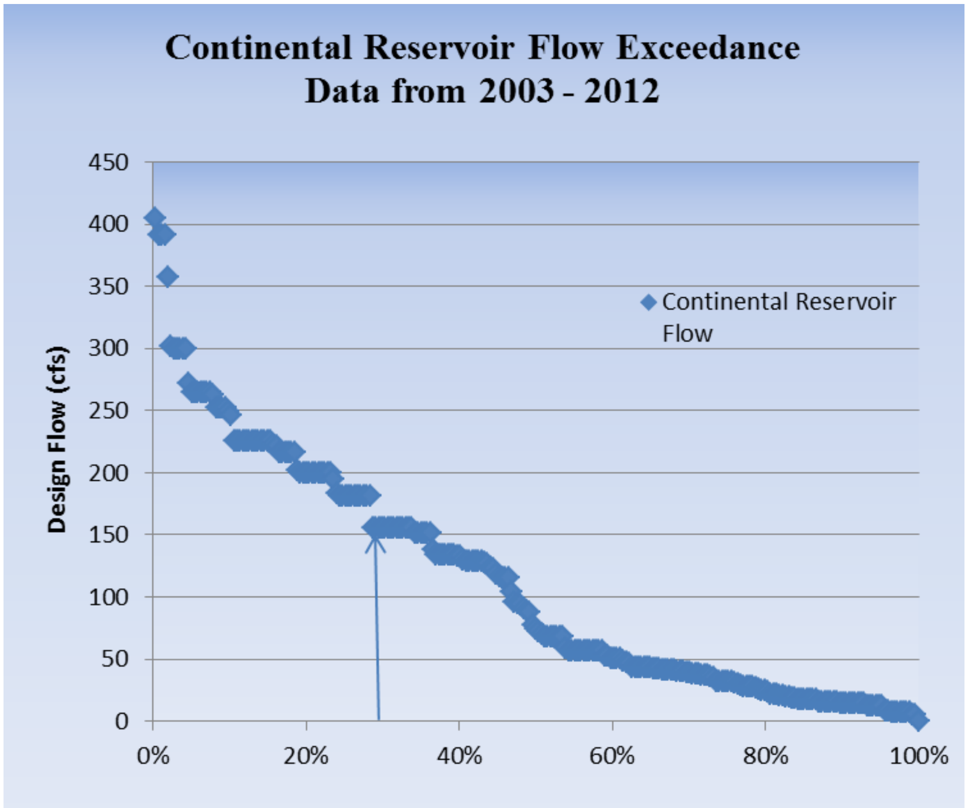
For some sites, the needed flow information could not be found or identified using the CDSS website and data. In these cases, flow information was attempted to be found using United States Geological Survey (USGS) data. USGS provides historical and current data on the nation's water resources. To search USGS gages that may apply to dams, USGS sites were mapped along with each dam on Google Earth. The aerial image for each dam was visually inspected to identify if gages in the vicinity were acceptable. One dam site's data was obtained from USGS gage data.

<u>Analysis</u>

<u>*Design Flow*</u>

Daily flow records in CDSS were researched from a maximum of 10 years to develop design flow values. Design flow is considered to be the value in which 30% of the time the historic flow will be exceeded (USBR 2011). Therefore, exceedance curves are developed to mathematically identify this value (see figure below). Days reported with null releases were not considered.

Ten years of data, starting in 2003, was identified as an adequate duration to investigate flow patterns and develop design flow assumptions for each structure, however only 31 structures had available data from 2003. For all the other sites investigated, data was gathered from the most recent time period available. It is realized that operational patterns may have changed within this time frame with either increased or decreased flow releases. A comparison of design flow values calculated from 10 years of data and 5 years of data was done. Of the 31 sites, 3 sites were analyzed from 2007 as the comparison of data suggested recent operations had changes.



EXCEEDANCE CURVE FOR CONTINENTAL RESERVOIR. THIS DATA IS MATHEMATICALLY CALCULATED FROM AVAILABLE FLOW DATA FOR THE SITE. THE CALCULATED 30% EXCEEDANCE VALUE IS 155 CFS.

Design Head
The same method for calculating design flow is used to calculate design head when stage data is available. Stage data is reported in CDSS on a monthly basis and therefore not as specific as daily flow data. When available, the monthly stage value was assigned to the daily flow value when it occurred in the same month. Stage data was available for 38 sites.

For sites without stage data available, design head was measured from Google Earth. The problem with this approach is Google Earth head values are a snapshot in time. There is no way to know what a 30% head exceedance value is from this snapshot. However, at this time, this is the best data available for these sites.

Missing Data
There were 27 sites where data could not be found. These sites used the data provided by ORNL.

Quality of Data
This study used existing data resources available through research. Dams were not visited and detailed assessments were not conducted. Therefore, a rating system of High, Medium, and Low was assigned to the data to identify the quality of data.

- High
  - High quality was identified as data which came from existing resources such as completed feasibility studies and existing FERC permits.
- Medium
  - Medium quality data was identified as sites that had a minimum of 4 years of data starting from 2012.
- Low
  - Low quality sites were those with fewer than 4 years of data, sites with data that could not be found after 2007, or sites with missing data which used ORNL estimates

Calculations
The number of days flows were released in the time record available was divided by the number of years of data availability. This computation is identified as an estimated Average Days per Year flow was released from the site. This value is used to calculate the estimated Average Annual Energy (kWh). Similarly, the Average Months per Year calculation was the total number of months flow was released in the time record available divided by the number of years of data availability.

The power equation is as follows:

$$P = \frac{Q\ x\ H}{11.8}\ x\ 0.85$$

Where:
P = Power (kW)
Q = Design Flow Value (cfs)
H = Design Head Value (ft)
11.8 = Unit Conversion Factor
0.85 = Assumed Efficiency of System

Data summarized in each analysis includes :

- Year flow data begin
- Year flow data ended
- Average Months/Year the site released flow
- Average Days/Year the site released flow
- Design flow value
- Design head value*
- Power (kW)
- Average Annual Energy (kWh)

*Indicates sites with Google Earth values for head

Delta County Analysis and Results

Five dam sites were identified in Delta County as technically feasible; they are shown in Figure 1 and listed in the below table.

NID ID	Dam Name	Design Head (ft)	Design Flow (cfs)	Estimated Capacity (kW)	Annual Generation (MWh)
CO00639	WARD CREEK	35	3	8	5.5
CO00604	OVERLAND #1	42	50	151	188
UC-22	CRAWFORD DAM	135	31	303	1217
UC-46	FRUITGROWERS DAM	28	17	29	124
CO00629	CARL SMITH	36	20	51	146

Statewide Analysis and Results

Statewide, there were 106 dam sites evaluated, of which 102 dams were found to have the technical potential to generate hydroelectricity. The locations of these dams are presented in Figures 2 through 8; each figure displays one of the seven Water Divisions in the State of Colorado, each Division corresponding to a major drainage basin. Information on each dam site can be found in Table 1, included in the Appendix.

Conduit Drops Evaluation

An initial study of conduit drops was performed by Applegate Group in 2010. The study identified many technologies and addressed interconnection issues. Colorado State University (CSU) advanced the project by visiting a number of canals across the state and verifying a method of using GIS to identify drops. We used a similar method in this study to locate drops using GIS. The data from CSU field investigations was used to confirm the GIS analysis.

Topography and ditch line data is available to identify drops, but the data to calculate the power at each drop (i.e. flow data) is not available across the whole state. Instead of trying to calculate with specificity the potential energy in every ditch, we proposed to identify drops across the entire state and then focus on Delta County to calculate the potential at sites.

Gaps and Methodology for Narrowing Target List

The ditch alignments were gathered for each study area. For Delta County, the individual ditch alignments provided by the Delta Conservation Service were merged into a single shapefile and this formed the record of ditch alignments in that area. For the remainder of the state, the ditch alignments obtained from the NHD were used.

Although these two sources of data did contain most of the ditch alignments in their subject areas, some minor ditches were not present in the datasets, resulting in a potential gap in the analysis. It was assumed that these minor ditches would likely have little hydropower potential, and thus their absence would have minimal impact on the overall results. Additionally, the quality of the Delta Conservation Service and NHD ditch/canal alignments varied depending on location. It was not uncommon for the digitized alignments to differ from the true alignments (as identified from orthorectified aerial photographs) by 50 feet or more. This divergence from the true alignment would potentially result in actual drops being missed or false drops being identified. Manual review of the analysis results was performed to minimize the errors resulting from this misalignment.

The analysis proceeded by first extracting the underlying NED elevation information along each ditch/canal alignment. The elevation information obtained was in the form of 10 meter by 10 meter raster cells. A neighborhood around each elevation cell of the ditch/canal alignment was investigated to determine the range of elevations surrounding that cell. The size of the neighborhood was varied depending on the drop height that was to be identified. For drop heights of 10 feet or greater, the elevation range was based on a 40 meter diameter circle around each cell; in other words, the elevation of the ditch 20 meters upstream was deducted from the elevation of the ditch 20 meters downstream to determine the elevation range surrounding that location. For large drops, which were defined as 150 feet or greater, the elevation range was based on a 300 meter diameter circle around each cell, in other words, the elevation of the ditch 150 meters upstream was deducted from the elevation of the ditch 150 meters downstream to determine the elevation range surrounding that location.

The elevation ranges which met or exceeded a certain threshold were isolated and mapped to show potential locations of conduit drops. For the short drop analysis (which searched for drops of 10 feet or greater), the threshold elevation range was 4 meters, or 10% of the neighborhood diameter. For the tall drop analysis (which searched for drops of 150 feet or greater), the threshold elevation range was 45 meters (or 15% of the neighborhood diameter). The potential locations of conduit drops were manually scanned with aerial photo and topographic maps forming the background to confirm or deny the presence of a conduit drop at that location. Drops identified by this methodology were compared to drops identified by previous studies from the USBR and CSU. This comparison verified the methodology as adequate in picking up the presence of most drops, but found that drops less than around 10 feet were not consistently identified. The inability of the methodology to reliably identify these drops is largely attributable to the resolution of the underlying 10m NED, which is composed of 10m by 10m squares and has a vertical accuracy of around eight feet. Simply put, the elevation data is too coarse to reliably pick out short drops.

When an actual drop was identified, the height of the drop was measured from NED data, the potential length of pipe required was measured, distance to the nearest major road, and the source for flow information at the drop (if any) was recorded. In the case of drops identified in Delta County, the actual average flows at the location and number of days in operation was determined based on the Delta Conservation Service data, allowing the potential generation capacity and annual electricity generation to be estimated for these sites. Additionally, the actual distance to transmission/distribution lines was assessed based on data provided by DMEA, allowing accurate estimates of transmission cost to be made.

In many cases, sites without a source of flow information were assessed to be spill / return structures, located on small laterals off the main ditch, or near the tail end of the main ditch. Barring a major change in operations under the ditch system, such locations are unlikely to have much potential for hydropower development.

In some situations, a drop was identified that was previously investigated by the USBR in its 2012 conduit report. Such sites were noted and the capacity of the site determined by the USBR was recorded.

Delta County Analysis and Results

The conduit drops identified in Delta County are summarized in Table 2 in the Appendix. The location of the identified conduit drops within Delta County is displayed in Figure 1.

Within Delta County, a total of 77 distinct conduit drops were found. The drop heights ranged from 5 feet to 575 feet, with typical flows ranging from negligible levels to over 100 cfs. Using the power equation previously defined, these 77 conduit drops were estimated to have a theoretical power potential of approximately 3.1 MW. Due to the seasonal nature of flows through the structures, these conduit drops have an overall capacity factor of 44%, theoretically generating approximately 12,100 MWh per year.

Lessons Learned from Delta County Analysis

The Delta County analysis found that sites with high flows, high drops, or a combination of the two were most likely to be economically feasible. Therefore, the statewide search focused on finding drops greater than 10 feet on systems that divert 100 cfs or more, or drops greater than 150 feet on systems of any size diversions.

Statewide Analysis and Results

Based on the lessons learned from the Delta County analysis, the statewide search focused on identifying two categories of conduit drops: drops of any height under systems that divert high flows (defined as diversions of 100 cfs or more since 2005), and drops of 150 feet or greater under systems that divert at any rate. The CDSS database was queried to identify those structures which have diverted at least 100 cfs since 2005; the NHD ditch/canal alignments associated with these structures were then manually identified and isolated into a shapefile that would be analyzed for drops of any height. All of the NHD ditch/canal alignments were part of a second shapefile which was analyzed for drops of 150 feet or greater.

The conduit drops identified statewide are summarized in Table 3 in the appendix. The locations of the identified conduit drops for each Division are shown in Figures 2 through 8. The below table summarizes the sites found in each Division.

			Site Information		
Colorado Water Division	**Number of Sites**	**Total Drop Height of all sites**	**Number of sites Evaluated by USBR**	**Number of Sites with Flow Information**	**Number of Sites without Flow Information**
1	23	1,594	0	19	4
2	4	408	1	2	2

3	0	0	0	0	0
4*	104	8,507	23	100	4
5	43	4,507	9	17	26
6	8	1,070	0	4	4
7	18	1,204	4	6	12
Total	200	17,290	37	148	52

*Includes conduit drops identified in Delta County

On-farm Pressurized Irrigation Systems

On-farm Pressurized Irrigation Systems have not previously been investigated for hydropower potential. We believe that the achievability of these projects is very high and the opportunity may be significant, as shown by recent development and available grant programs through the NRCS.

To identify the magnitude of the opportunity, a GIS based analysis was performed both on Delta County and statewide. More detailed ditch information was available in Delta County, therefore we feel more confident that we were able to identify all of the opportunity in Delta County. We also were able to check the quality of the data in Delta County in more detail. The statewide data is less detailed, meaning that some ditches are not mapped, which may result in a slightly underestimated potential in the rest of the state.

Gaps and Methodology for Narrowing Target List

The irrigated land data was filtered to only review those fields that are identified by CDSS as being served by a surface water source; fields irrigated solely with groundwater were disregarded from this analysis and they were assessed to have no hydropower potential. Utilizing GIS, the irrigated land data was overlaid on the NED data and an analysis was performed to determine the average elevation of each irrigated field.

Next, the elevation raster along the ditch alignments developed during the conduit drop analysis was converted into an integer format by rounding the elevations in each cell along the ditch/canal alignments to the nearest foot. An allocation algorithm was then performed on each study area which assigned each location within the study area the integer elevation of the nearest upgradient ditch/canal, in effect showing the nearest conduit which can deliver water to a location via gravity.

The average elevation of the ditch serving a given field was then determined using GIS. The available head was estimated by deducting from this value the average elevation of the field itself. The average straight-line distance to the source ditch was also determined for each irrigated field. Available flow to a given field was estimated assuming one cfs for every 40 acres of irrigated land; this value is a general rule of thumb that has its basis in the "duty of water" commonly sought in the early appropriations for Colorado water rights.

A pivot operates with a water pressure of approximately 40 psi. In order to achieve this level of pressure, roughly 100 feet of head is needed. Therefore, only those fields with an available head of 100 feet or more were investigated further.

The potential hydropower generation capacity was calculated using the power equation previously defined, assuming available head and flow was equal to the design head and flow. The potential thus calculated includes the head required to pressurize the irrigation system. An additional estimate of the hydropower generation capacity in excess of the power required to pressurize the system was also performed; this value represents the power available to offset other electrical loads or mechanically drive the pivot itself.
The ditch/canal alignments were obtained from the Delta Conservation Service Data or the NHD data. As previously discussed, this data lacks the alignments of some minor ditches. If the ditch actually serving an area is not present alignment information, this method will erroneously assign the next most upgradient ditch serves the area. Such situations typically result in the ditch identified as serving an area being located unreasonably far from the irrigated field; the results from the Delta County analysis were reviewed to in depth to determine at what distance from the analysis was likely to give erroneous results. Situations where the source was located at this distance or greater were disregarded as likely being incorrect.

This method does not account for those instances when water is pumped from a down gradient ditch to serve a given field. These instances are likely rare and thus are not expected to impact the analysis results significantly.

An additional gap in information is the exact location on the ditch where water is diverted from (i.e. the turnout or headgate to the farm). Although the Delta Conservation District data does provide some information identifying which parcels were served from which headgates, this information was not specific or clear enough to quickly assign diversion locations. Therefore, the methodology adopted in this study assumes that the point on the ditch nearest a given field is the point where water is turned out to that field. For a reconnaissance level estimate such as this one, such an assumption is appropriate.

Pressurizing a field may require running pipe from the source ditch through parcels of varying ownership. The impact of rights-of-way and easement requirements was beyond the scope of this study.

Finally, the size of the field was not considered a barrier to pressurized system development. The area of some fields may be less than the traditional 130 acre center pivot, but it is possible that nearby small fields could be aggregated into a single larger field or other sprinkler methods (such as ½ pivot, ¼ pivot, wheel lines, hand lines, etc.) could be used.

Delta County Analysis and Results

The irrigated lands with potential for pressurization identified in Delta County are summarized in Table 4 in the appendix. The location of the identified lands with pressurization potential within Delta County is displayed in Figure 1.

According to the CDSS 2005 survey of irrigated lands in Division 4, there are roughly 79,000 acres of land under irrigation in Delta County. Our analysis found that 19% of these lands, or approximately 14,900 acres, are candidates for pressurized irrigation systems. Only 10% of the lands that are candidates for pressurized irrigation system are already sprinkler irrigated; the remaining 90% are predominantly flood or furrow irrigated.

The power generation potential of all of the lands that are candidates for pressurized irrigation systems (in excess of the power needed to pressurize the irrigation systems themselves) was estimated to be 3.4 MW. Depending on the situation at a given parcel, this excess power could be used to offset other electrical loads or to mechanically drive the sprinkler system itself.

Lessons learned from Delta County Analysis

An in-depth review of the Delta County analysis results found that the estimate of potential head to a given field was usually falsely inflated if the head was greater than 500 feet or the distance to the source was greater than 2.5 miles. Therefore, the statewide search disregarded those fields that exceeded these parameters unless additional information was available indicating the estimated heads were valid.

Statewide Analysis and Results

The potential pressurized systems identified statewide are summarized in Table 5 in the appendix. The locations of the identified potential pressurized systems for each Division are displayed in Figures 2 through 8. The below table summarizes the quantity of potential found in each Division.

						Power Potential [kW]	
Colorado Water Division	Total Irrigated Area [ac]	Number of Fields with Pressurization Potential	Area with Pressurization Potential [ac]	% Total Area with Pressurization Potential	% of Pressurization Area Already Under Sprinklers	Including Pressurization	In excess of Pressurization
1	830,546	774	22,558	2.7%	33%	5,192	1,132
2	465,526	702	24,704	5.3%	9%	8561	4,114
3	512,001	111	2,239	0.4%	16%	567	164
4*	286,254	1,136	49,598	17.3%	5%	19,310	10,382
5	226,375	1,271	38,441	17.0%	13%	14,861	7,942
6	213,973	227	13,853	6.5%	6%	4,975	2,481
7	176,454	729	24,073	13.6%	15%	7,598	3,265
Total	2,711,129	4,950	175,466	6.5%	13%	61,064	29,480

*Includes lands identified in Delta County

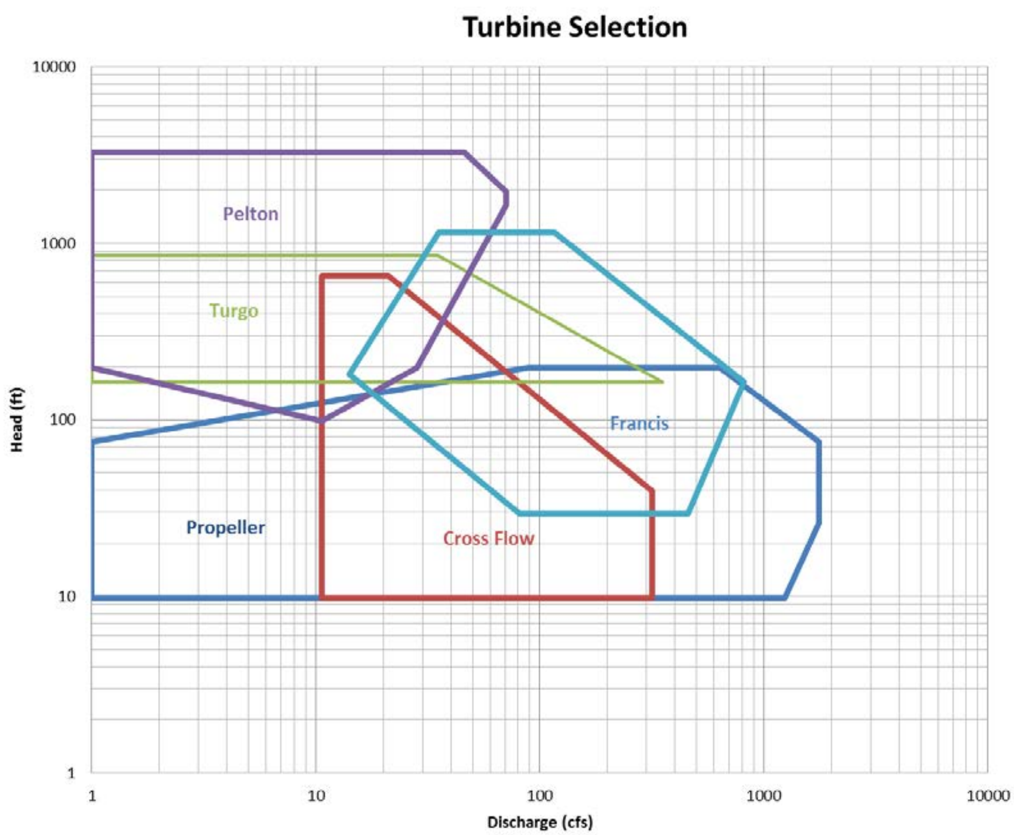
Available Hydropower Technologies

Throughout this study we have focused on “standardized turbine,” turbines that are designed and manufactured to fit a certain range of head and flow conditions. Manufacturers of standardized turbines generally choose 2 to 5 standard models to cover a larger range of sites, but allow for standardization. This standardization can reduce the cost of a turbine, but also limits the sites for which it is appropriate. Alternatively, a custom turbine is designed and manufactured for specific site conditions. A custom turbine will match the conditions at a site, and extract an optimal amount of energy from a site, but in general the cost will be higher than a standardized turbine. Standardized turbines may also be best suited for other conditions at a site, e.g. bolt onto an existing pipe, or fit into an existing structure. This again limits the standardized turbines applications, but may reduce the cost of the civil infrastructure needed to develop the site.

Available Turbines for Non-Powered Dams and Conduit Drops

Custom Turbines

Turbines are initially selected for a site based on the head and flow characteristics. The following chart shows the general ranges for the five major turbine types. After this initial selection, other factors may affect the final selection including other site conditions and flow patterns. Each turbine type will be described below, the descriptions were provided by the Department of Energy, Water Power Program (http://www1.eere.energy.gov/water/hydro_turbine_types.html).



Propeller

Kaplan Turbine (Credit: GE Energy)

A propeller turbine generally has a runner with three to six blades in which the water contacts all of the blades constantly. Picture a boat propeller running in a pipe. Through the pipe, the pressure is constant; if it isn't, the runner would be out of balance. The pitch of the blades may be fixed or adjustable. The major components besides the runner are a scroll case, wicket gates, and a draft tube. There are several different types of propeller turbines:

- Bulb turbine - The turbine and generator are a sealed unit placed directly in the water stream.
- Straflo - The generator is attached directly to the perimeter of the turbine.
- Tube turbine - The penstock bends just before or after the runner, allowing a straight line connection to the generator.
- Kaplan - Both the blades and the wicket gates are adjustable, allowing for a wider range of operation.

Francis

Francis Turbine (Credit: GE Energy)

A Francis turbine has a runner with fixed buckets (vanes), usually nine or more. Water is introduced just above the runner and all around it and then falls through, causing it to spin. Besides the runner, the other major components are the scroll case, wicket gates, and draft tube.

Cross Flow

A cross-flow turbine is drum-shaped and uses an elongated, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner. It resembles a "squirrel cage" blower. The cross-flow turbine allows the water to flow through the blades twice. The first pass is when the water flows from the outside of the blades to the inside; the second pass is from the inside back out. A guide vane at the entrance to the turbine directs the flow to a limited portion of the runner. The cross-flow was developed to accommodate larger water flows and lower heads than the Pelton.

Pelton

Pelton Wheel (Credit: GE Energy)

A pelton wheel has one or more free jets discharging water into an aerated space and impinging on the buckets of a runner. Draft tubes are not required for impulse turbine since the runner must be located above the maximum tailwater to permit operation at atmospheric pressure.

A Turgo Wheel is a variation on the Pelton. The Turgo runner is a cast wheel whose shape generally resembles a fan blade that is closed on the outer edges. The water stream is applied on one side, goes across the blades and exits on the other side.

Standardized Turbines

The following descriptions for standardized turbines were adapted from the 2011 Low Head hydro report written by Applegate Group and Colorado State University.

Energy Systems and Design – LH1000

The LH1000 is a small propellor type turbine suitable for sites with about 2 cfs, and 10 feet of head. In these conditions one unit will produce 1 kW of DC electricity. The LH1000 uses a permanent magenet alternator. An inverter is utilized for AC systems, and the turbine can be also be used to directly to charge batteries using a charge controller. This turbine can be purchased for between $3,000 and $4,000.

LH100 (Credit: Energy Systems & Design)

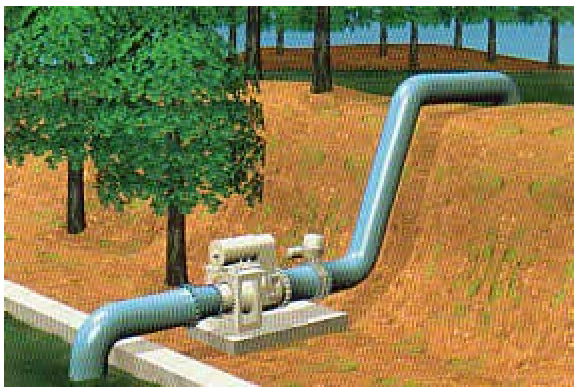
Energy Systems and Design – Stream Engine

The Stream Engine ® is a very small turgo turbine capable of producing 2 kW. The turbine is generally used in an off grid situation to charge a battery bank, similar to an off grid solar system. The turbines can be placed in parallel to increase the capacity. Connecting to the grid will require additional equipment.

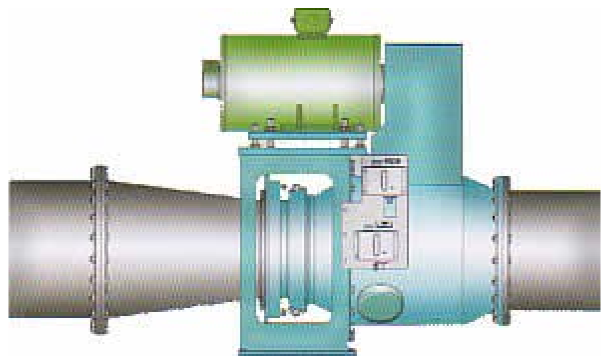
Toshiba International – Hydro-eKIDS

The Hydro-eKIDS are manufactured in three standard sizes, S, M and L. The runners can be chosen from three alternatives to match the site conditions. The runner vane angle will also be adjusted to match site conditions. These turbines can be installed in series or in parallel to accomidate a range of head and flow conditions.

These are propeller type turbines and would be best suited for installation in an existing pipe or in an outlet of a reservoir. The Type S produces between 5 and 35 kW, the Type M between 5 and 100 kW, and the Type L between 10 and 200 kW. Toshiba provides the turbine, generator and controls in one package for this type of turbine. As seen in the figure below, the turbine can be installed with a siphon intake so not to distrurb the existing dam.



Example installation with siphon intake



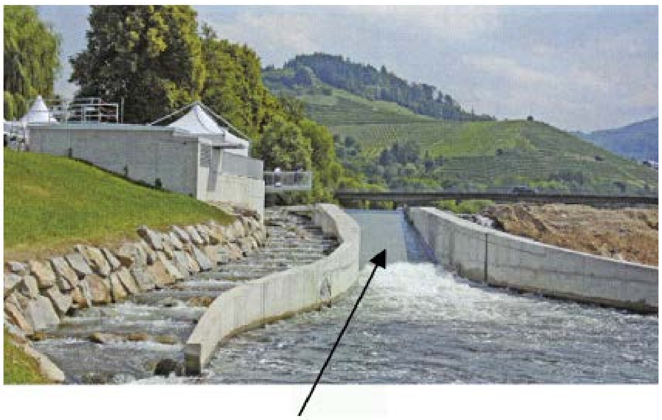
TYPE M (WWW.TIC.TOSHIBA.COM.AU)

Ossberger Canada – Movable Power House

Ossberger has recently developed a Kaplan turbine / generator package for specific low head applications called the “Movable Power House”. This hydropower station is a completely submersible package developed to reduce overall costs of low head projects. Typical project installations would be within a weir or hydraulic control structure. There are currently five (5) power stations in production in Europe. The generator is a permanent magnet, direct connect type. This is not exactly a standardized turbine, but a standardized configuration. The Kaplan turbine would be custom designed and manufactured, but the “powerhouse” has been standardized to reduce civil infrastructure costs. This turbine will be considered when a Kaplan turbine is the appropriate selection.

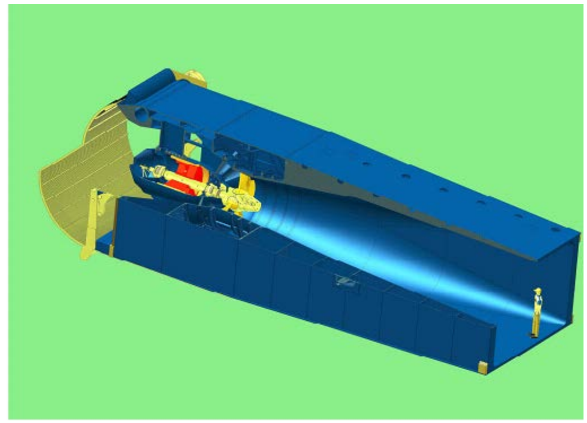
Working Range					
Head (ft)		Flow (cfs)		Power KW	
3.3	26.2	35.3	882.2	350.0	900.0

Dimensions			
Length (ft)	Width (ft)	Height (ft)	Weight (tons)
62.3	17.4	14.1	143.0



MOVABLE POWER STATION

Movable Power House Instalation



KAPLAN-TURBINE TYPE BE

Movable Power House

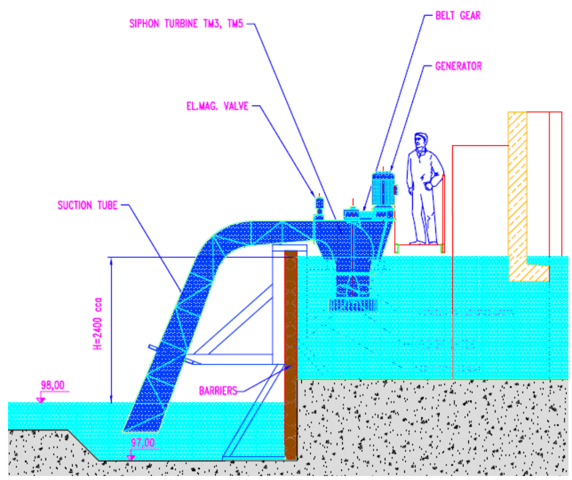
Mavel - MicroTurbines

Mavel is a turbine manufacturer located in the Czech Republic, with a distributor in Massachusetts. The company recently announced a Micro Line of turbines for low head projects. They have successfully installed these turbines in Poland, Japan, and Latvia. Mavel has installed turbines in the United States, but not turbines from the Micro Line. The Mavel Micro Turbines are a propellor type turbine designed for low head, low flow site conditions. Currently three sizes of the turbine is offered, the TM3, TM5 and TM10. The range of site conditions suitable for each turbine is listed in the table below. These turbines can be installed in parallel if there is more flow available than a single turbine can handle, as shown in the photograph below.

	TM3	TM5	TM10
Head (ft)	5-20	5-20	7-16
Flow (cfs)	5-14	25-50	70-175
Power Output (kW)	0.7-13	2-50	30-180

The siphon outlet on these turbines may be beneficial if there is an exisitng structure that needs to be bridged. Installing the siphon outlet may decrease installation costs if modifying the existing structure is not feasible.

TM10 Installation (www.mavel.cz)



Example Installation

Clean Power AS - Turbinator

The Clean Power AS Turbinator is a relatively new technology (first installation in 2010). The Turbinator is a turbine/generator combination machine designed to be used with low to medium head ranges. To minimize total hydroplant costs, attention has been emphasized on the turbine/generator construction to reduce civil works cost to a minimum by providing a robust, simple design. The machined is designed to be exposed to the elements and requires minimal operation facility infrastructure. The generator is a permanent magnet, direct connect type.

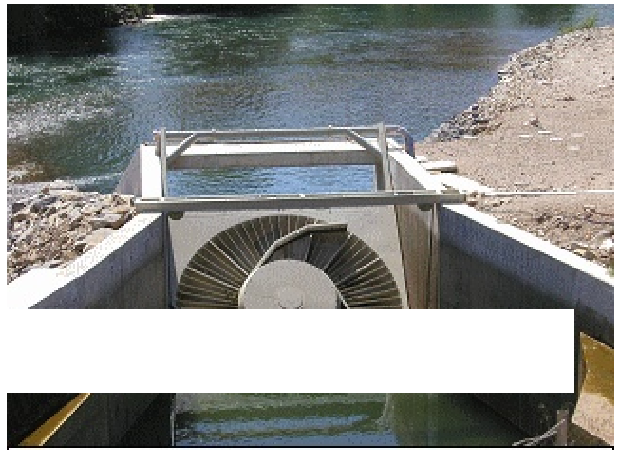
	T500	T600	T750	T1000	T1250	T1500
Hydraulic Diameter (mm)	500	600	750	1000	1250	1500
Flow Rate (cfs)	18-46	28-71	46-109	71-173	138-268	215-420
Power Range (kW)	75-280	55-550	70-670	190-1700	370-2000	190-3300

Turbinator

Hegset Dam mini Hydropower plant

Very Low Head Turbine

This turbine has been installed in at sites in France, Canada and other Eurpoean countries. The company is eager to expand its buisiness into the United States. The turbine will be offered in five sizes to accomidate a range of site conditions. This turbine is intended to be installed in an open channel, and a head differential will be created across the turbine. This turbine would probably be best suited for the larger canals in Colorado, and in an existing structure to reduce the infrastructure costs. At the maximum discharge rate shown below this turbine operates at almost 80% efficiency.



VLH Turbine installation

Maximum discharge through the turbine at the specified head (cfs)					
	Runner Diameter (feet)				
Net Head (feet)	***11.6***	***13.1***	***14.8***	***16.4***	***18.4***
4.6	367	470	593	731	918
4.9	381	484	614	756	950
5.2	396	501	632	780	982
5.6	406	516	653	805	1010
5.9	417	530	671	830	1042
6.2	431	544	689	851	1070
6.6	441	558	706	872	1095
6.9	452	572	720	897	
7.2	463	586	742	918	
7.5	473	600	759	936	
7.9	484	614	777		
8.2	491	625	791		
8.5	501	639	809		
8.9	512	650	823		
9.2	523	660			
9.5	530	675			
9.8	540	685			
10.2	547	696			
10.5	558	706			

Power Produced (kW)					
	Runner Diameter (feet)				
Net Head (feet)	***11.6***	***13.1***	***14.8***	***16.4***	***18.4***
4.6	113	144	182	226	284
4.9	125	159	202	251	315
5.2	138	175	223	276	347
5.6	151	192	244	302	380
5.9	164	209	266	329	415
6.2	178	227	288	357	450
6.6	192	245	311	386	486
6.9	207	264	335	415	
7.2	222	283	359	445	
7.5	237	302	384	476	
7.9	253	322	409		
8.2	269	343	435		
8.5	285	363	462		
8.9	302	385	488		
9.2	318	406			
9.5	336	428			
9.8	353	450			
10.2	371	473			
10.5	387	496			

Natel Energy SLH

Natel Energy's hydroengine is a unique design using the uplift created as water passes by curved blades. This turbine is in the pilot project stage, and is ready for commercial development. A 10 kW turbine was recently installed in an irrigation canal in Buckeye, Arizona. The turbine was installed in an aging check structure that needed repair. These turbines will be offered in 5 sizes with the following site conditions and power productions. The power produced is at the high end of the flow range and at 13 feet of head.

Model	Head (ft)		Flow (cfs)		Power (kW)
SLH-10	3.3	19.7	15	37	32
SLH-100	3.3	19.7	127	310	266

The turbine is offered as a water-to-wire package including the turbine and draft tube, generator, switchgear, SCADA compliant controls, as well as installation and maintenance support. This system is intended to be installed in an existing drop or structure, requiring little civil improvements. This system is referred to as a hydraulic engine instead of a hydraulic turbine, because of the unique design, claimed to be the first fully flooded two-stage water impulse engine. This design is fish friendly, allowing fish and debris to pass through the engine without damage.

Cross section of the hydroengine (www.natelenergy.com)

Pilot installation in Buckeye, AZ(www.natelenergy.com)

Andritz Atro Hydrodynamic Screw Turbine

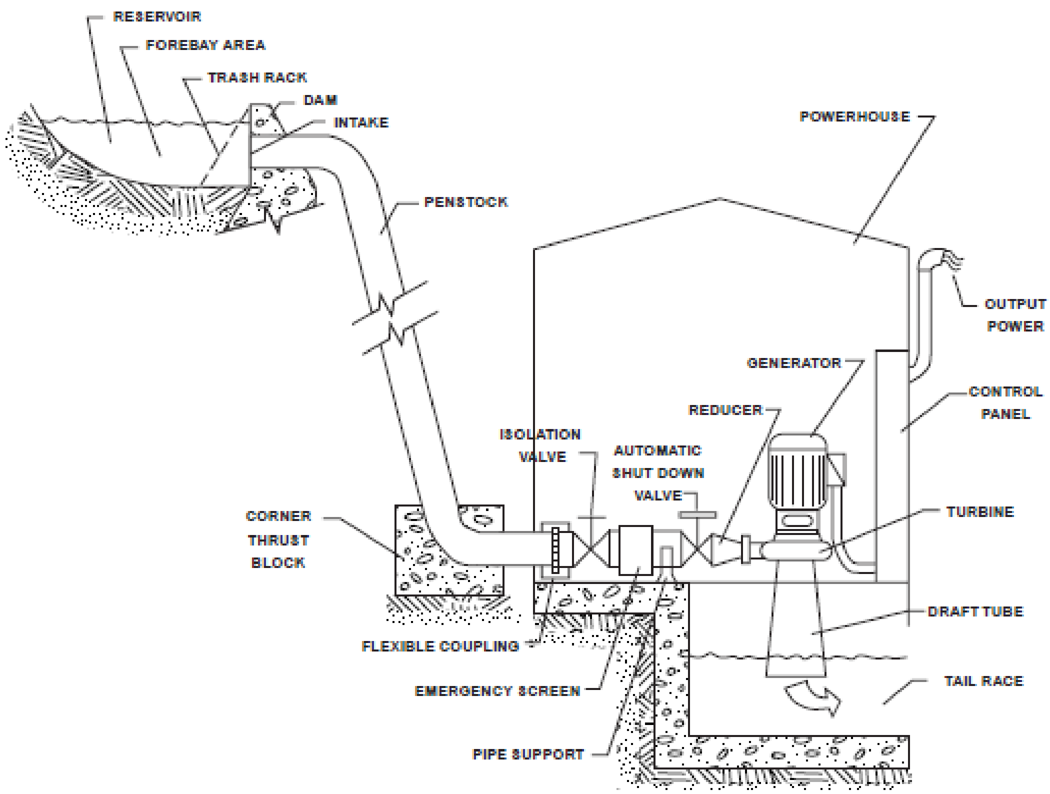
Ritz-Atro is a German Company that supplies pumps to the water and wastewater community, specializing in Archimedean screw pumps. As a result they also manufacturer "hydrodynamic screws", which are turbines based on the Archimedean screw principle. The hydrodynamic screw portion of the company was purchased by Andritz and is now known as Andritz-Atro. These turbines are fish friendly and do not require fine screening. These turbines also maintain their efficiency over varying heads and flow rates. Eighty percent of peak efficiency is maintained down to 30% of the design flow rate, and it can operate at as low as 5% of the design flow rate. Turbines are supplied in many sizes and custom designed for each site. They can produce up to 300 kW of power, using up to 200 cfs, and heads up to 33 feet.

There are a number of distributers and installation in the United Kingdom. It appears that some of these distributers are also interested in entering the U.S. market. This turbine could be used in existing concrete structures with a unique geometry, as seen in the photograph below.

Hydrodynamic Screw (www.ritz-atro.de)

Pumps as Turbines

Several manufacturers offer "pumps as turbines" (PAT), which is exactly as the name implies, a pump running backwards to produce electricity as a turbine would. In North America, Cornell Pumps in cooperation with Canyon Hydropower offer a water to wire package including necessary the controls for interconnection. In this report we have referenced specific models offered by Cornell Pumps and Canyon Hydro. There are other manufacturers that may offer different sizes, but we believe that Cornell Pumps and Canyon Hydro supplies a representative range of turbines.



Typical PAT configuration (Cornell Pump Catalog)

Pressurized Irrigation Systems

Several center pivot irrigation system hydropower projects have been installed in Colorado in recent years. These projects leverage funding from the NRCS for irrigation efficiency improvements and utilize the infrastructure for the hydropower project. Two recent projects were highlighted by the Colorado Energy Office through case studies and are included in Appendix A through C. These two projects take different approaches to capturing the power of water, but the overall scheme is the same as described below. A third and fourth alternative may be considered for higher head sites and is explained in more detail below.

Wenschhof Hydro

This project utilizes a custom Pelton turbine and generator to produce electricity which is net metered with the utility to offset the demands of the irrigation system and the rest of the ranch. The demands include a pump on the center pivot which is used to pressurize the higher elevation portions of the field, the motors that move the center pivot, and building demands. The pipeline which supplies water to the center pivot also carries water farther downhill to the power plant. The water that enters the power plant is used to irrigate fields that are further downhill from the power plant. This configuration uses excess water to produce electricity.

Required Conditions: At least 100 feet of head and excess water that can be run through the pipeline and used downstream of the pivot. Utility power needs to be available at site.

Advantages: Electrical demands can be offset increasing the revenue of the project

Disadvantages: The generator adds to the overall project cost, requires FERC approval and a net metering agreement from the utility.

Bear River Ranch Hydro-mechanical

The Bear River Ranch project produces mechanical energy instead of electricity. The pipelines are configured in the same manner as the Wenschhof project, but the turbine is connected to the hydraulic pump of the center pivot instead of a generator. Water is carried through the pipeline to both the turbine and the sprinklers. The sprinklers are entirely gravity pressurized, and the water that goes through the turbine is discharged after the turbine and used to flood irrigate lower fields. This configuration uses excess water to produce mechanical energy

Required Conditions: At least 100 feet of head and excess water that can be run through the pipeline and used downstream of the pivot.

Advantages: Simple, low cost design. FERC and utility approval not required, utility power not required, can be off-grid.

Disadvantages: Revenues limited to only offsetting the cost of operating the pivot.

Barton Ranch Hydro

Both of the previous examples use excess water to create energy, an alternative possibility is using excess head (if available) to produce the energy. The sprinklers require about 40 psi of pressure to function, which is equal to about 100 feet of head. If head in excess of 100 feet is available, it is possible to reduce that pressure prior to the sprinkler and use that captured energy to either produce electricity or mechanical energy as explained in the previous two examples.

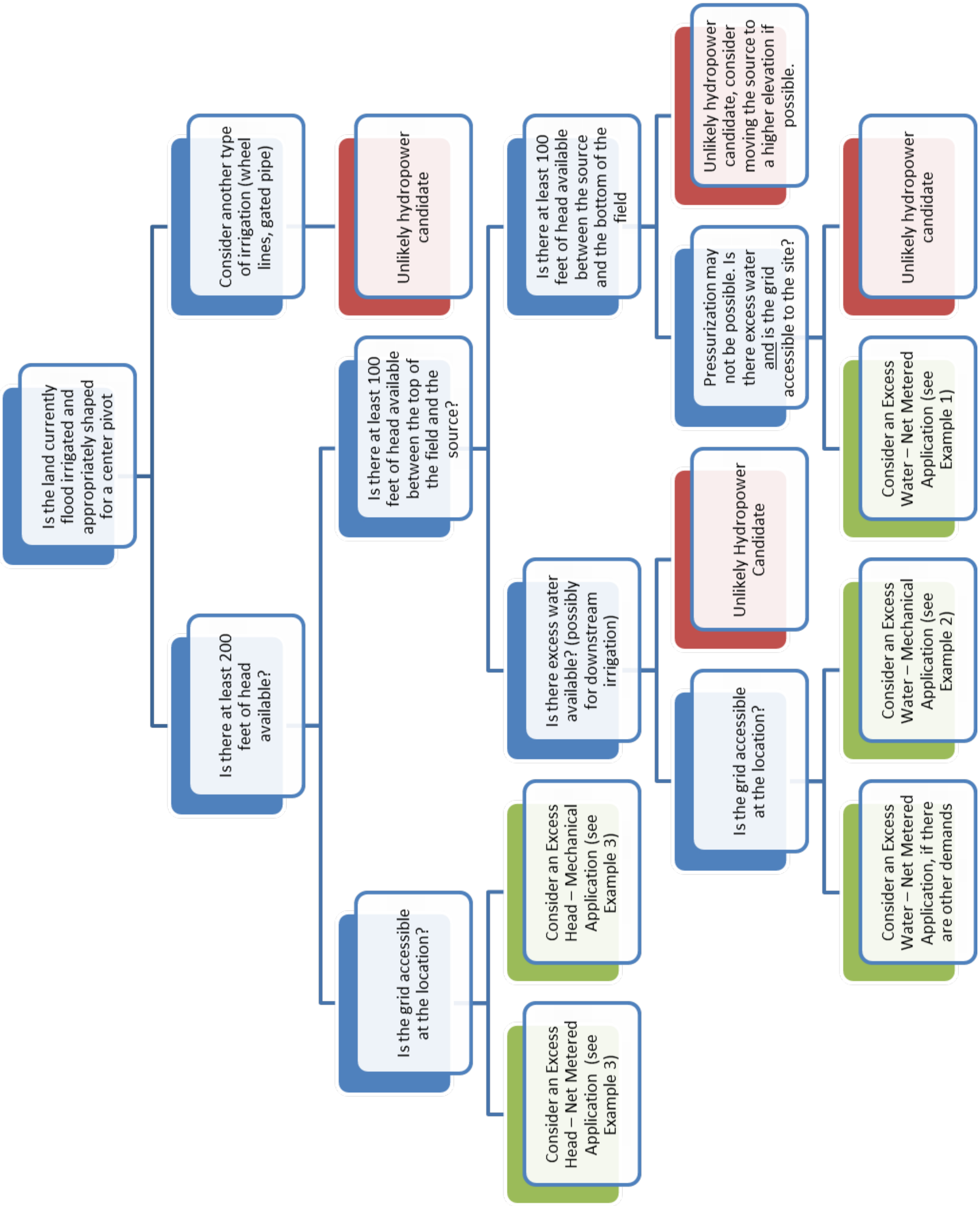
Required Conditions: Excess head above 100 feet (amount depends on the topography and size of the pivot)

Advantages: If producing mechanical energy FERC and utility approval not required, utility power not required, can be off-grid.

Disadvantages: Slightly more complicated piping and valve design. Additional equipment is required to move the pivot without irrigating, which may or may not be an issue.

A decision tree is included on the next page to assist in explaining when one system would be used over another.

Pressurized Irrigation System Turbine Selection Chart



Basis for Development Cost Estimates

Development costs were estimated for the statewide dam sites and the Delta County conduit drops identified. The cost to develop hydropower at a dam or conduit drop is equal to the sum of the turbine and generator costs, the pipeline/penstock cost, the electrical interconnection cost, the civil works cost, and the design and permitting costs. The costs for pressurized on-farm systems are explained based on three case studies of recently developed projects.

Turbine and Generator Costs

Each site was evaluated to determine whether a standardized or custom turbine would be required. Standardized turbines are typically sold in a combined turbine and generator package. Allowances for the cost of a generator were made when estimating the custom turbine cost. The turbine which was most cost effective was selected for the basis of developing the turbine cost estimate.

Standardized Turbines

Turbine and generator costs were obtained from manufacturers for standardized turbines. Some of the costs were available on line; others were obtained from the turbine manufacturer directly. Each turbine was assigned one cost, although a range of costs may have been provided. The actual cost will depend on the conditions at each site and may vary slightly from the cost used in this report. Turbine costs from manufacturers that were used in this report are shown in the table below.

Manufacturer	Type	Model	T&G Cost
Energy Systems and Design	Turgo	Stream Engine	$ 4,500
	Axial	LH-1000	$ 5,000
Harris Hydroelectric	Pelton	Harris	$ 2,200
NatEL America	HydroEngine	SLH-10	$ 80,000
		SLH-100	$ 600,000
Very Low Head Turbines	Kaplan	3150	$ 750,000
		3550	$ 881,000
		4000	$ 1,029,000
		4500	$ 1,131,000
		5000	$ 1,227,000
Mavel	Axial	MT3	$ 45,000
		MT5	$ 90,000
		MT10	$ 250,000
ANDRITZ Atro	Archimedean Screw		$ 401,000
			$ 575,000
			$ 758,000
Toshiba International	Fixed Propeller	Hydro-eKIDS Type S	
		Hydro-eKIDS Type M	
		Hydro-eKIDS Type L	$ 630,000
Clean Power	Fixed Propeller	T500	$ 790,000
		T600	$ 950,000
		T750	$ 1,110,000
		T1000	$ 1,360,000
		T1250	$ 1,440,000
		T1500	$ 1,590,000

Additionally, pumps-as-turbines (PATs) were considered where the head and flow conditions were appropriate (generally the very smallest projects). The cost of PATs were estimated based on quotes supplied by Canyon Hydro for Cornell PAT packages, which include generator, switch gear and controls. The minimum cost for a PAT package is estimated to be $60,000 up to 60kW in capacity, above 60kW, a cost of $1,000 per kW was used.

Custom Turbines

In general, this report considers standardized turbines assuming that they will provide the most cost effective solution to most sites. Depending on the site conditions and the limited range of a standardized turbine, a custom turbine may be more appropriate. The method for estimating the cost of a custom turbine differed depending on the type of turbine required.

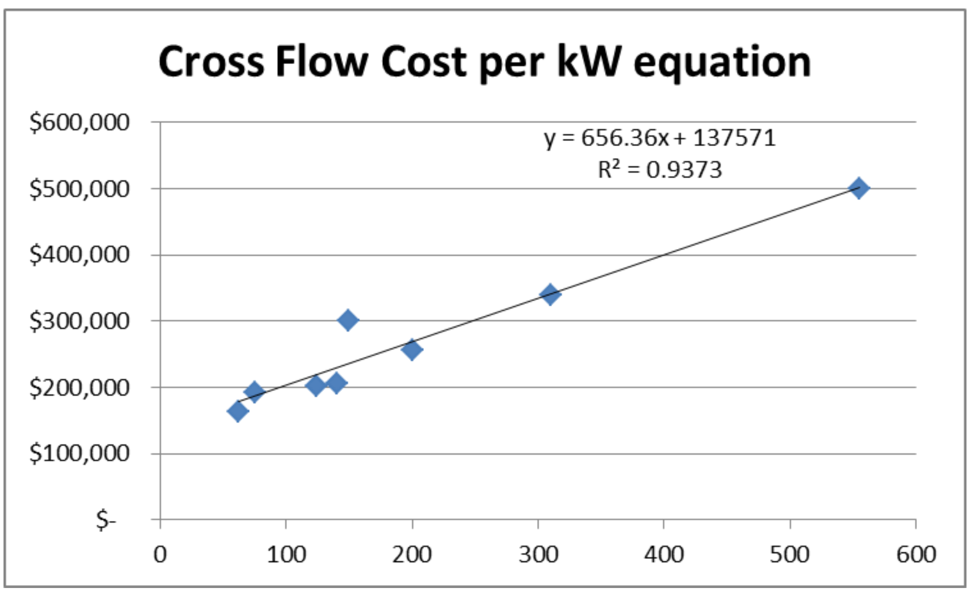
Kaplan or Francis Turbine

At sites that were appropriate for a Kaplan or Francis turbine, the USBR cost estimation tool[1] was used to estimate the direct construction costs associated with retrofitting an existing dam that is undeveloped for hydropower. This tool provides a full development cost including turbine/generator, penstock/pipeline, electrical interconnection, civil works, and design/permitting. The underlying cost estimate equations are documented in the USBR's March 2011 Hydropower Resource Assessment at Existing Reclamation Facilities report.

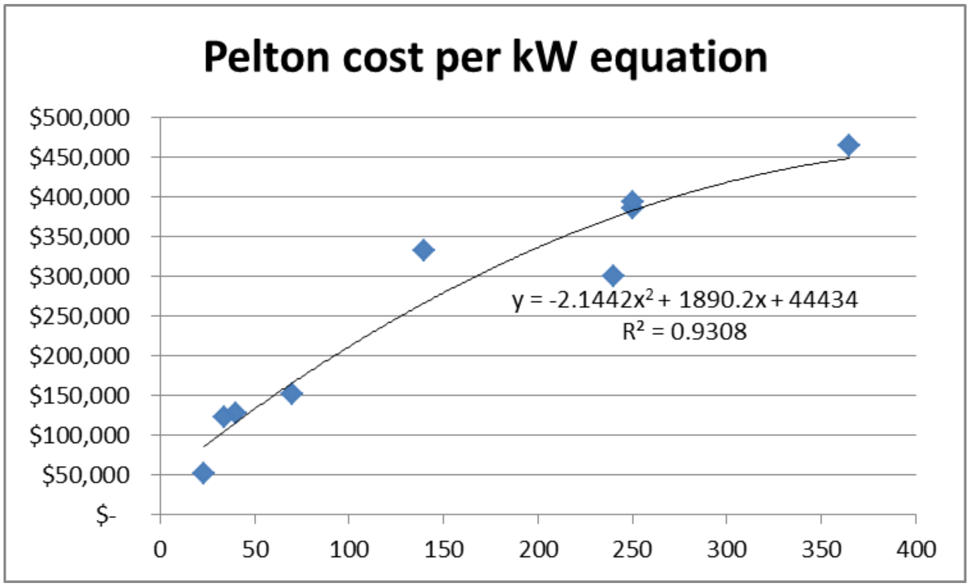
Pelton or Cross Flow Turbine

Pelton or Cross Flow turbines were evaluated where site head and flow conditions indicated these turbine types would be appropriate. All sites with more than 10 cfs fell within the range of a custom Cross Flow turbine and all sites with more than 130 feet of head and more than 1 cfs of flow fell within the range of a custom Pelton Turbine.

The costs of custom Pelton and Cross Flow turbines were determined using a regression equation through a sample of turbine and generator costs. The sample size was relatively small (8-9 examples), but the range covered the range of sizes seen in the Delta County sites and statewide dams. Also the regression equation represented the sample well with R-squared values above 0.93.



[1] USBRHydroAssessmentToolVersion2.0xlsm; obtained from http://www.usbr.gov/power/, November 5, 2013



Penstock

For each site involving a penstock, the length was determined with GIS and the diameter was chosen by limiting the velocity in the pipe to 10 feet per second using the average flow rate. The cost of material and installation was estimated to be $4/inch per linear foot. This typical cost was chosen through experience of the authors.

Interconnection

For the Delta County conduit drops, the distance to the nearest meter or transformer was determined from DMEA data. Single phase service was assumed to be adequate for conduit drops 100 kW or less, whereas three phase service was assumed to be required for sites with greater capacity. Costs to extend electrical service to the hydropower sites were assumed to be $12 per foot for single phase and $30 per foot for three phase.

For the statewide dam sites, the distance to transmission lines had to be estimated. The distance to major roads as indicated by U.S. Census TIGER/Line data was utilized as an estimate for transmission distance.

Transformer cost was estimated to be $2,500 per 100kW of installed capacity. This cost is based on typical costs seen in previous feasibility studies.

Powerhouse / Civil Costs

Civil infrastructure and powerhouse costs were estimated across all sites. This is a rough estimation, and likely an optimistic, low cost. Standardized turbines, PATs, Pelton turbines, and Cross Flow turbines were assumed to have civil costs equal to the turbine/generator cost. Due to the low turbine cost for very small standardized turbines such as the LH1000 and Stream Engine, the civil costs for these turbine types was estimated to be twice that of the turbine/generator costs. Standardized turbines that are specifically designed to reduce infrastructure costs such as the Turbinator, Toshiba, VLH and Mavel were estimated to have lower civil costs, only half of the turbine and generator cost.

Design and Permitting

Permitting and design costs were estimated to be 10% of the cost of the turbine/generator and powerhouse/civil costs. The permitting and design costs are included in the USBR cost estimation tool for the Kaplan and Francis dam projects.

Economic Feasibility of Projects

The economic success or feasibility of a hydropower project may be evaluated using several different measures. The simplest measure is the length of payback based only on the installation costs and the first year annual revenue, known as "simple payback". This calculation does not take into account annual costs, escalation in costs or revenue, or the interest rate of borrowed funds. This measure is easy to understand and calculate, although may not accurately represent the time to payback the project.

Another economic measure commonly used to evaluate hydropower projects is the Internal Rate of Return. This measure is appropriate for an investor to evaluate the cash contribution to a project assuming the remainder will be borrowed. We do not believe that this measure is appropriate for a project owned by a rancher, the rancher is more concerned about recuperating the investment and how long that will take than how much money his investment is making.
In this study we have compared the annual revenue to the initial development cost on a cash flow basis. We assume that for a project to be considered economically feasible to an agricultural producer, the initial cash investment needs to be recuperated within 10 to 20 years. A number of assumptions need to be used in the cash flow analysis to represent actual conditions. It is assumed that the developer will need to invest 10% of the project cost initially, and the remainder of the project cost will be borrowed through a low interest loan for 30 years at 2% interest. The loan costs also include a 1% origination fee. The value of power and the cost of operation and maintenance are assumed to escalate 2% annually.

As an aside, with these criteria and assumptions, the project will have a minimum IRR of 14% to 8% after 30 years (based on either 10 or 20 year break even criteria). This would be considered an excellent to very good investment. Also, if the project breaks even in 10 years the project will never have a negative cash flow, if the project breaks even in 20 years, there will be negative cash flow in first year, and positive after that. That is, in year 1 or 2, the project is producing positive revenue that is used to pay back the initial investment.

Using this type of calculation allows us to evaluate any site based on only two financial factors that have been calculated from site conditions; annual revenue and development cost.

Non-Powered Dams Economic Feasibility

The economic feasibility of the identified non-powered dams was evaluated, both for Delta County and statewide.

Delta County

None of the five technically-feasible Delta County non-powered dams passed the test for economic feasibility, based on development costs and annual revenue. The Bureau of Reclamation studied the feasibility of Crawford and Fruitgrowers Dam and found them to have a cost benefit ratio of 0.64 and 0.06 respectively, meaning a hydropower project would generate less revenue than it would cost to develop over 40 years.

Dams were not found to be an area of potential in Delta County if wholesale power purchase rates remain around $40 per MWh.

Statewide

Of the 102 technically feasible non-powered dams identified statewide, 17 could be economically feasible and break even within 10 years, and 23 sites could break even within 20 years. These 23 sites account for 75% of the total capacity although they are only 22% of the total sites. This shows that the largest capacity projects are the most economically feasible. The 23 economically feasible sites total approximately 40 MW of capacity, 25 MW of that capacity (6 projects) is currently under development, leaving about 15 MW of untapped, economically feasible potential throughout the state.

Four of the remaining 17 projects are small, net metered projects that would need an on-farm demand to be economically feasible, and would be similar to the on-farm pressurized projects described in this report. The average development cost of the other 13 projects is about $2 million.

Colorado Water Division	Number of Dams with Technical Potential	Estimated Total Capacity of technically feasible projects [kW]	Estimated Total Capacity of economically feasible projects over 10 years [kW]
1	38	4,989	380
2	10	16,984	14,024
3	7	4,750	0
4	16	15,518	13,581
5	19	9,889	8,481
6	8	679	178
7	4	746	0
Total	102	53,555	36,644

Conditions Necessary for a Feasible Project

Of the 27 dams whose generation capacity was small enough to qualify for net metering, only three were found to be feasible with a 10-year break even basis. However, all three had insufficient data to perform our own analysis of generation potential, which forced us to rely on the ORNL data. Prior reviews have indicated that the ORNL capacity estimation methodology yields potentially unrealistically high capacity and energy estimates. Therefore, it is probable that no dam small enough to qualify for net metering is feasible.

Of the 79 dams whose generation capacity was too large to qualify for net metering, 14 were feasible on a 10-year break even basis. Generally, these dams:

- Had a combination of high flow and high head available. If a dam had at least 140 feet of head and a design flow of at least 150 cfs, then it was feasible.
- Had large quantities of flow at any head. If a dam had a design flow of at least 1,000 cfs, then it was feasible regardless of head.
- Dams with heads between 40 feet and 120 feet and design flows between 10 cfs and 400 cfs generally required a plant factor of at least 50% to be considered feasible.

This study did not investigate the feasibility of adding hydropower to each dam's outlet structure. This may significantly affect the cost of the project. The current outlet works would need to be evaluated for pressure and hydraulic capacity. For the purposes of this study we assumed that the outlet works could be retrofitted with minimal costs, although this needs to be confirmed on a case by case basis.

Conduit Drop Economic Feasibility

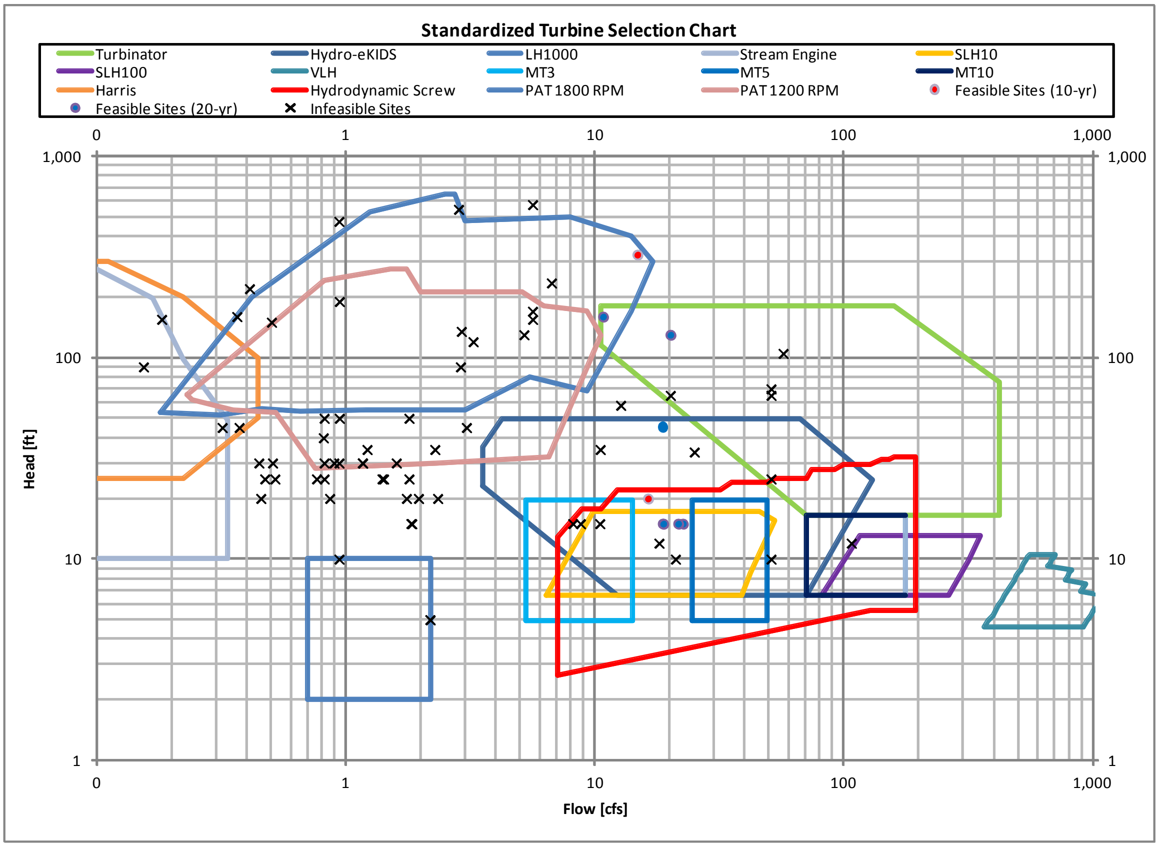
A study of the economics for each of the Delta County conduit drops was conducted to determine which were economically feasible. Because flow data was not readily available for the conduit drops identified statewide, the hydropower generation potential is currently unknown and an economic feasibility study was not completed for these locations.

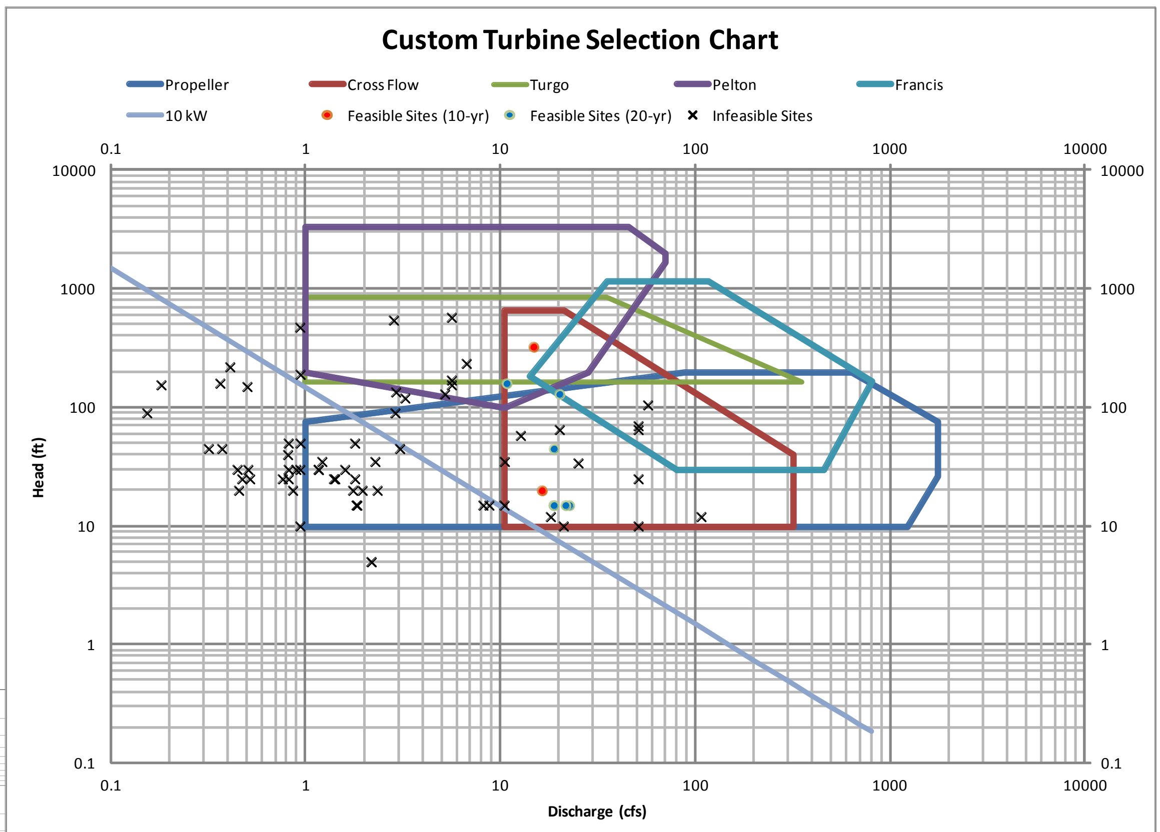
Delta County

Of the 77 conduit drops identified within Delta County, 59 were found to be technically feasible, meaning there was an existing standardized or custom turbine whose operation envelope encompassed the head and flow conditions at the site. The expected annual revenue from each drop was calculated as the product of the electricity generated and the power purchase rate. If a site was able to be net metered (i.e. power potential of 25 kW or less based on current laws) then the power purchase rate was assumed to be the net metering rate of $95 per MWh; sites larger than 25 kW were assumed to receive a wholesale power purchase rate of $40 per MWh. The development costs for the technically feasible projects were estimated as the sum of the penstock cost, transmission cost, turbine cost, permitting costs, and civil works costs.

The economic feasibility of a project was assessed by comparing the expected revenue to the development cost. The feasibility of the conduit drop projects is very sensitive to the power rate received for generated electricity and any "green" incentives offered. Under current conditions and assuming a 1% operations and maintenance cost, we determined that nine sites with a total capacity of 0.8 MW were feasible for a payback period of 20 years or less. Only two sites with a total capacity of 0.4 MW were feasible for a payback period of 10 years or less.

Roughly half of the sites which were economically feasible were sufficiently small to qualify as net metered projects; the other half of feasible projects generated between 60 kW and 350 kW.


Standardized Turbine Selection Chart
Turbinator
Hydro-eKIDS
LH1000
Stream Engine
SLH10
SLH100
VLH
MT3
MT5
MT10
Harris
Hydrodynamic Screw
PAT 1800 RPM
PAT 1200 RPM
Feasible Sites (10-yr)
Feasible Sites (20-yr)
Infeasible Sites
Head [ft]
Flow [cfs]
0
1
10
100
1,000


Custom Turbine Selection Chart
Propeller
Cross Flow
Turgo
Pelton
Francis
10 kW
Feasible Sites (10-yr)
Feasible Sites (20-yr)
Infeasible Sites
Head (ft)
Discharge (cfs)
0.1
1
10
100
1000
10000

Conditions Necessary for a Feasible Project

Feasible projects tend to have higher flows available. The nine feasible Delta County conduit drops had flows averaging 18 cfs, whereas flows to the infeasible Delta County conduit drops averaged half that at 9 cfs. Feasible projects also tend to have a longer operating period, which translates into more electricity generation; the feasible drops had an average season length of 200 days, while the infeasible drops had an average season length of 165 days (over a full month shorter).

Whether or not a site qualified for net metering also greatly impacted the conditions required for a project to be feasible. If a site qualified for net metering, then in order to be feasible:

- The actual capacity of the site needed to be very close to the net metering generating capacity cutoff level of 25 kW. Sites that didn't have at least 20 kW of generating capacity were all infeasible; sites that had 20 kW of generating capacity or more were all feasible.
- The site needed to have a low drop to flow ratio; the feasible net metering sites had an average ratio of 0.8 ft / cfs, while the infeasible sites had an average ratio of 88.3 ft / cfs.

If a site was too large to qualify for net metering, then generally the site needed to have flow between 10 and 20 cfs with head between 100 feet and 400 feet in order to be feasible, although exceptions to this rule did occur.

Generally, drop height did not appear to be very relevant to the feasibility of a drop. A low drop height typically means the site would qualify for net metering, so a low drop doesn't necessarily mean the site will be infeasible so long as it has sufficient flow to result in between 20 kW and 25 kW of generating capacity.

On-Farm Pressurized Irrigation Systems Economic Feasibility

The economic feasibility of developing an on-farm pressurized irrigation system is highly site dependent; therefore it is difficult to make any broad conclusions regarding the economic feasibility of installing on-farm pressurized irrigation systems on the lands where potential was identified. However, we believe that the achievability of these projects is very high and the opportunity may be significant, as shown by recent development and available grant programs through the NRCS.

Conditions Necessary for a Feasible Project

The conditions necessary for a feasible on-farm pressurized irrigation system project will depend on whether it is a new sprinkler installation or a retrofit of an existing sprinkler installation.

Newly Installed System

If the goal is to produce power in addition to pressurizing the sprinkler system, then excess pressure and/or flow is needed. If there is an excess of pressure, and inline turbine can be used to burn some of the pressure in the production of electrical or mechanical energy. If there is an excess of flow, some of the water can be diverted to the turbine while the remaining flow goes to the sprinkler. Any water run through the turbine can either be returned to the stream system or used to flood irrigate other areas.

Proximity to the grid is not required. Locations remote from the grid can covert hydropower into mechanical energy to drive the sprinkler system, which could result in much less cost than extending electricity service to the location. If a connection to the grid is available, hydropower generated at the site could be used to offset other nearby electrical loads.

If electricity is produced, then a net metering arrangement maximizes the savings provided by the system since power is offset at the retail rate. Because electrical loads may not be in close proximity to the location of hydropower generation, the ideal situation is for a utility to allow net metering across several interconnection points, although this is not yet allowed in Colorado.
If used to net meter other electrical loads, the timing of the loads should be well aligned with the timing of hydropower generation. In the case of pressurized irrigation systems, this means electrical loads should have the highest demand during the irrigation season.

Retrofit Existing Sprinkler Systems

The upfront cost of replacing flood irrigation methods with a sprinkler system is a common barrier to development. The addition of hydropower (for instance, to offset the fuel or electricity costs associated with a sprinkler system) may be sufficient to entice a previously reluctant irrigator to make the investment, but this is not guaranteed. Retrofitting an existing sprinkler system is an attractive option since the irrigator has already made the decision to convert to sprinkler irrigation, thus removing this barrier to development.

If the existing system received funding from the NRCS for system installation, then the NRCS may not provide additional funding for retrofitting the system. For instance, the NRCS Environmental Quality Incentives Program (EQIP), which funds projects that conserve water and energy, limits applicants to $300,000 in funding during any six year period unless the project is found to have “special environmental significance”, in which case the a petition can be submitted to raise the six-year funding cap to $450,000.[2] Also, if a pipeline is already in place but a new pipeline is required due to a change in pressure or flow requirements to support hydropower generation, the NRCS may not provide funds to replace it.

An existing sprinkler system which currently uses an open ditch to deliver water would be a favorable retrofit because the NRCS may pay for the piping under its EQIP program due to the water conservation benefits of reduced seepage. If a pipeline already exists to deliver water to the sprinkler system, the site would be unfavorable if the pipe was designed such to burn off excess pressure via friction. In this case, a hydropower retrofit would require replacing the existing pipeline. The site would be favorable if the excess pressure is not burned off but is instead reduced through a pressure-reducing valve (PRV). The PRV can be replaced with a turbine to accomplish the same pressure reduction, but with the benefit of hydropower generation.

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[2] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/, accessed November 4, 2013.

If the existing pivot is fuel-operated (i.e. diesel), then this likely means electrical service is not available at the site since, if given a choice, a pivot operator would likely chose electricity instead of diesel since it is the least expensive option over the long term. Since electrical service is not available without a large investment, these fuel-operated pivots are probably candidates only for hydromechanical systems. Therefore, the retrofit can only proceed if the existing pivot was manufactured by TL. This decision tree would quickly weed out retrofits on fuel-operated pivots that are infeasible. If the existing pivot is electricity-operated, then the retrofit can be hydroelectric or hydromechanical. Thus, it is irrelevant who manufactured the existing pivot.

A cost-effective retrofit is one that is favorable in all of the above conditions. However, a site that is highly favorable in a few conditions may outweigh the fact that it is unfavorable in other conditions. This is a site-specific determination.